Biological Resources

Summary

Over time, Puget Sound has become a less hospitable place for many of the organisms that reside within it. As discussed in the previous chapters of the *Update*, a variety of stressors affect Puget Sound's biological resources. From the Sound's water to the land of the entire Puget Sound basin, impacts to the Sound's biological resources (species and habitats) are manifested in many ways. These and other items are discussed in more detail later in the chapter:

- The Puget Sound basin has experienced extensive loss of tree cover in the last 25 years.
- Seven species of Puget Sound marine fish are currently being considered for possible protection under the federal Endangered Species Act.
- Three of the five species of diving birds discussed in this chapter appear to be declining in abundance.
- A rapid inventory of non-indigenous species in Puget Sound reported 10 of these species that had not previously been found. This brings the total number of known non-indigenous species in Puget Sound to 52.

Populations of many important species in the Puget Sound ecosystem have declined substantially in recent years, causing concern among natural resource managers. These declines have probably resulted from a number of human-induced stressors including overharvest, habitat loss and pollution, as well as natural processes such as cyclical

changes in temperature. Especially worrisome is the steady decline in abundance of adult Pacific herring that has occurred since the mid-1970s (see page 84). Pacific herring comprises a large part of the food base for Puget Sound carnivores (e.g., rockfish, codfishes, dogfish, lingcod, common murre, marbled murrelet, tufted puffin and harbor porpoise), many of which are also in decline (West, 1997). Harbor seals and California sea lions, protected from harvest since 1972 by the Marine Mammal Protection Act, are notable exceptions to this trend.

Findings

PSAMP investigators and other cooperating scientists monitor the abundance and health of key species or groups of organisms (such as harbor seals, salmon, herring, surf scoters and phytoplankton) as indicators of ecosystem health. Scientists monitor not only the abundance and distribution of organisms, but also their exposure to pollutants and changes in their habitats. This section presents the findings of investigations about the health of the plants, algae, invertebrates, fish and wildlife that call Puget Sound home.

Loss of Tree Cover in the Puget Sound Basin

Human impacts to the vegetation of the Puget Sound basin were revealed by a recent analysis of local tree cover over a 25-year period. American Forests, a Washington, D.C.-based non-profit organization, analyzed satellite imagery of 3.9 million acres of land in the east side of the Puget Sound basin to determine how forest cover in the basin changed between 1972 and 1996. The analysis showed that the landscape of the basin changed dramatically:

- Areas with dense vegetation and tree canopy coverage (50 percent tree cover or more) declined by 37 percent—from 1.6 million acres to 1.0 million acres.
- Areas with sparse tree cover (less than 20 percent) more than doubled—from 25 percent of the region to 57 percent of the region.

American Forests (1999) estimated that the loss of trees resulted in a 35 percent increase in stormwater runoff from the study area. Replacing this lost stormwater retention capacity with reservoirs and other engineered systems would cost $2.4 billion. American Forests also estimated that the lost tree canopy would have removed approximately 35 million pounds of air pollutants annually, at a cost to society of approximately $95 million.

Nearshore Vegetation

Aquatic vegetation provides structural habitat for many organisms and supports the food web through primary production. Because of their recognized ecological importance, many types of aquatic vegetation (e.g., algae, eelgrass and kelp) are protected by law.

The amount of aquatic vegetation nationwide has decreased dramatically over the last 70 to 100 years (Tiner, 1984). Substantial losses have occurred in Puget Sound, especially near urban centers (Bortelson et al., 1980). Tidal marshes and swamps in Puget Sound have declined more than 70 percent from their historic extent (Thom and Hallum, 1991). Loss of other types of aquatic vegetation due to human activities has probably occurred, but the extent of these losses is not well documented. Eelgrass beds are thought to be decreasing due to human impacts on the physical environment and water quality. Canopy-forming kelp is believed to have increased Sound-wide during this century, perhaps due to increased coarse sediment habitat associated with shoreline modification (Thom and Hallum, 1991). Local losses of historic kelp beds have also been reported (see, for example, page 82).

Vegetation Type	Acres	Percent
Eelgrass	14,000	84
Green algae	1,200	7
Salt marsh	950	6
Mixed algae	240	1
Kelp	200	1
Red algae	0.1	< 1
Brown algae	69	< 1
Spit or berm vegetation	39	< 1
Total	**17,000.1**	**100**

Table 14. Areal extent of nearshore vegetation types for Skagit County study area.

Nearshore vegetation losses are attributed primarily to changes in the physical environment. Loss of vegetation beds frequently occurs as a direct result of habitat conversion, such as dredging and filling. Historically, extensive vegetation bed losses occurred in estuaries due to conversion to uplands. Changes in the physical environment have also lead to indirect loss of vegetation through degradation of water quality, eutrophication, changes in sediment supply and changes in wave energy.

Inventory of Nearshore Vegetation. In 1999, the Department of Natural Resources released nearshore vegetation inventory information for 230 miles of shoreline in Skagit County and northern Island County. Inventory results are available on CD-ROM to assist in land-use planning and to facilitate a better understanding of linkages between habitats and species.

Using multispectral imagery, Natural Resources classified vegetation into one of eight categories: eelgrass, brown algae, kelp, green algae, mixed algae, salt marsh, spit and berm vegetation and red algae. Eelgrass was the most abundant vegetation type in the area (see Table 14), followed by green algae and salt marsh. These vegetation types were found predominantly in broad embayments in the study area, including Padilla Bay, Samish Bay and Skagit Bay.

The inventory illustrates the wide range of intertidal environments found in Puget Sound. Along rocky shores such as Deception Pass, canopy forming kelps and mixed algae beds alternated with pocket beaches containing green algae and eelgrass (see Figure 49, Color Section, page 113). Other more protected shores, such as Cornet Bay, contained extensive eelgrass beds on large tidal flats and high intertidal marshes (see Figure 49, Color Section, page 113).

Temporal Trends in Canopy-Forming Kelp along the Strait of Juan de Fuca. In the Puget Sound region, the canopy layer of a floating kelp bed is formed by two species—giant kelp *(Macrocystis integrifolia)* and bull kelp *(Nereocystis luetkeana)*—that have float-like structures to hold the upper portion of the plant at the surface. Other kelp species dominate the understory level, providing a dense layer of vegetation used as shelter for small invertebrates and larval fishes. This habitat has one of the highest primary productivities of any ecosystem on earth. Kelp beds extend along approximately 12 percent of the Puget Sound shoreline (Thom and Hallum, 1991). Some of the richest beds are along the Strait of Juan de Fuca.

Natural Resources' scientists mapped floating kelp beds on the Strait of Juan de Fuca from 1989 to 1998. These data suggest that the size of the kelp population was highly variable from year to year, yet stable over the long-term. Despite large year-to-year fluctuations as high as 57 percent in the total area of floating kelp beds in the Strait, the total area has not changed significantly over the last 10 years. During the study period, the total kelp bed area along the Strait of Juan de Fuca ranged from a minimum of 4,700 acres in 1989 to a maximum of 7,700 acres in 1998 (see Figure 50).

Shoreline physical characteristics

In addition to delineating nearshore vegetation, Natural Resources' nearshore inventory describes a set of physical shoreline characteristics that are known to affect the distribution of plants and animals. This data set is discussed on pages 25 to 26 in the Physical Environment chapter.

Figure 50. Kelp bed areas in the Strait of Juan de Fuca.

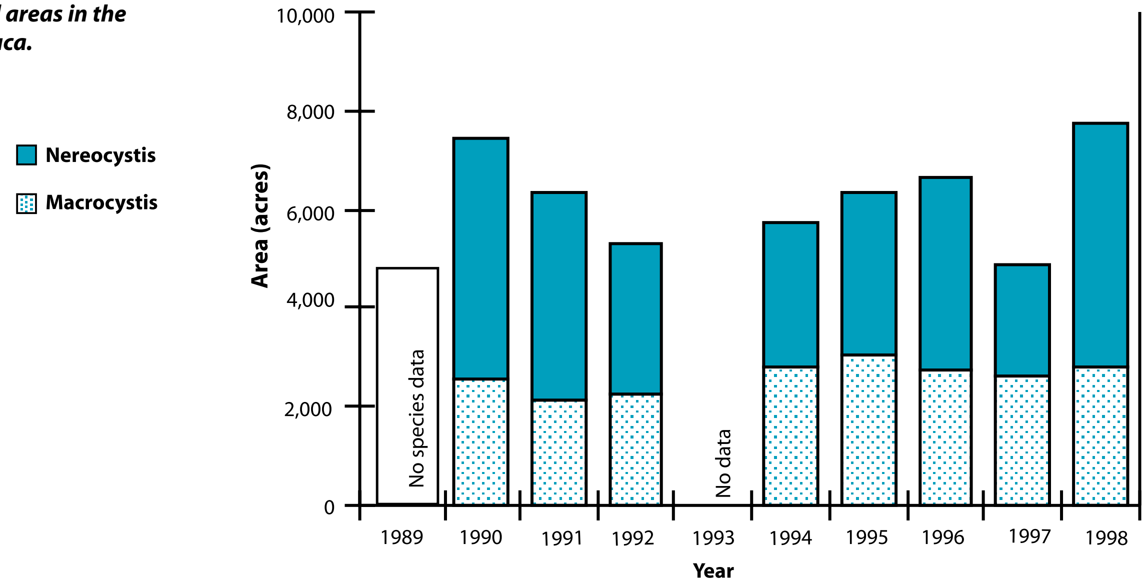
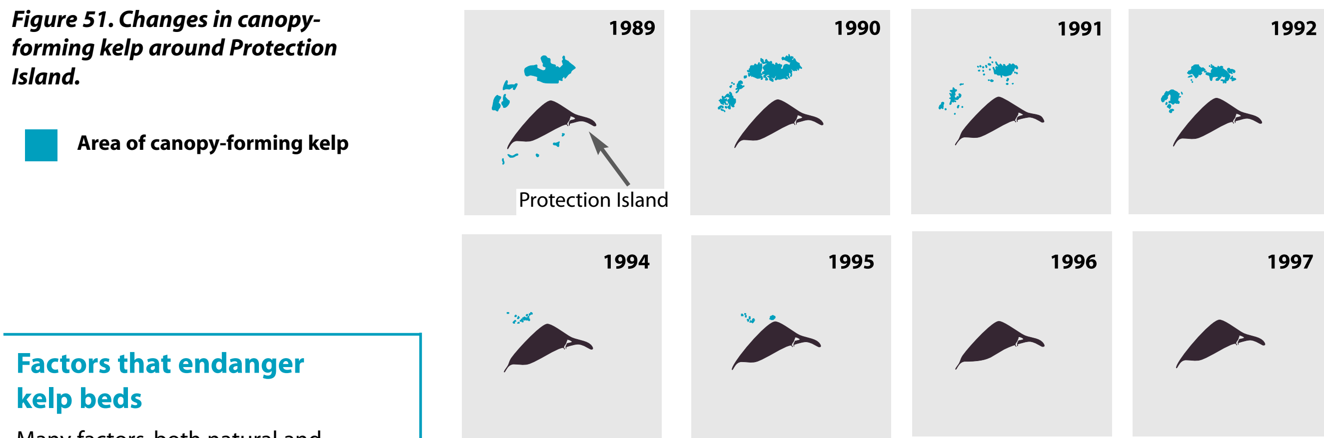


Figure 51. Changes in canopy-forming kelp around Protection Island.



Factors that endanger kelp beds

Many factors, both natural and human, affect the extent and composition of kelp beds. Elevated water temperature and intense sea urchin grazing can wipe out entire kelp beds. El Niño events stress kelp by producing severe winter storms and reducing upwelling events, which normally replenish the nutrients in the water column. Human influences on kelp beds include sewage and other runoff, which decrease water quality by changing nutrient levels and reducing light in the water column. Kelp plants can also be physically damaged by boat propellers and fishing gear. Commercial harvest of kelp is prohibited in Washington; consequently, this practice is not a significant factor in determining the extent and composition of kelp beds. Recreational harvest is permitted but Natural Resources does not have data on how this affects the kelp population.

The species composition of the floating kelp beds varied greatly from year to year, reflecting the two species' different responses to environmental conditions. Species dominance shifted during the study: bull kelp dominated from 1990 to 1992 and again in 1998; giant kelp was the dominant species in the other years.

Other differences between species of floating kelp were evident. Bull kelp populations consistently occurred in lower densities. Bull kelp also showed much higher year-to-year variation: the population decreased in area by 55 percent from 1994 to 1995 and increased by 250 percent from 1997 to 1998. The higher density and relative year-to-year stability of the giant kelp population is attributed in part to life cycle differences. Giant kelp is a perennial and can regrow new vegetative stipes from its base or holdfast. Bull kelp, on the other hand, is an annual and is usually removed by winter storms.

Some local losses of kelp have occurred. For example, the kelp bed north of Protection Island National Wildlife Refuge near Port Townsend began dwindling from 181 acres in 1989 until it completely disappeared in 1997 (see Figure 51). Human impacts to Protection Island are thought to be minimal because it is approximately four kilometers offshore and because of its status as a wildlife refuge. More research would be needed to understand the cause of this local trend.

Phytoplankton

Department of Ecology scientists monitor concentrations of chlorophyll as an indicator of the abundance of phytoplankton in Puget Sound's open waters. This monitoring, which relies on monthly sampling, allows scientists to quantify phytoplankton density but does not provide information on phytoplankton populations, communities or growth rates.

The *1998 Puget Sound Update* reported on Ecology's characterization of two seasonal patterns of chlorophyll concentrations in Puget Sound. The first pattern, the typical temperate condition, shows spring and fall blooms of phytoplankton (actually measured as elevations of chlorophyll-*a* concentrations). Ecology's 1996 to 1997 monitoring showed that Burley Lagoon (at the head of Carr Inlet) and Bellingham Bay exhibited this pattern.

The second seasonal pattern shows elevated chlorophyll-*a* concentrations in the summer as well as in the spring and fall. This pattern of summer blooms indicates that nutrient supplies are not depleted by growth of phytoplankton during spring blooms. The supply of nutrients can be natural (e.g., ocean input) or from human sources (e.g., on-site septic systems or agricultural wastes). Locations that exhibited summer blooms during 1996 and 1997 include Budd Inlet, East Sound (Orcas Island), lower Hood Canal and Holmes Harbor. The occurrence of summer phytoplankton blooms at these locations is consistent with the identification of these areas as sensitive to eutrophication (see page 45).

King County Department of Natural Resources scientists monitor chlorophyll-*a* and another pigment called phaeophytin monthly at several depths at nine open water stations in the central Puget Sound basin. Data collected in 1997 and 1998 show seasonal blooms occurring in late April (1998 only) and mid- to late-July. This pattern is consistent with previous years' findings.

Stations where there are potential sources of nutrient inputs (such as wastewater outfalls and industry) do not have higher chlorophyll-*a* levels than stations without nutrient inputs. The highest levels (greater than 30 µg/L) sampled during this two-year period were from the central basin in July 1998. Although the highest levels detected in 1998 were higher than in 1997, no trend is evident over the longer term.

Alternative approaches to monitoring chlorophyll concentrations

Monthly monitoring of chlorophyll concentrations at a few fixed depths is far from ideal and severely limits the ability of Ecology and King County scientists to draw conclusions about the spatial and temporal dynamics of phytoplankton growth in Puget Sound. Puget Sound scientists are actively investigating alternative monitoring approaches, including: moored sensors to increase temporal resolution; remote sensing to improve spatial coverage; and depth profiling to improve vertical resolution and support estimates of phytoplankton biomass.

Sediment-Dwelling Organisms

As part of the PSAMP's investigations of the condition of Puget Sound's sediments, Department of Ecology scientists collect information about the community of organisms that dwell in and on the sediment in open-water areas of the Sound. Measurements taken at Ecology's long term monitoring stations did not indicate that either species richness or total abundance of organisms was affected by contamination, probably because there were generally low levels of contaminants at the monitoring stations (Llansó et al., 1998). Nonetheless, Ecology scientists identified a few other indications of pollution effects in the composition of the sediment-dwelling communities at these stations. The primary example of such an effect was the community dominance by the polychaete worm *Aphelochaeta sp.* at locations where the sediments were enriched with organic pollution and/or showed moderate toxic contamination (Llansó et al., 1998).

However, the community of sediment-dwelling organisms is affected by a variety of stressors, not just organic enrichment and toxic contamination. The community responds to habitat changes, including sediment grain size alteration and seasonal reductions in dissolved oxygen concentrations. Ecology is continuing its long-term monitoring of the sediment-dwelling community to provide information about subtle shifts occurring in the soft habitats at the bottom of Puget Sound.

Ecology's baseline monitoring of sediment-dwelling organisms was conducted from 1989 to 1993 (Llansó et al., 1998). In 1997, Ecology scientists sampled a subset of the original monitoring network, focusing on 10 stations that represent the diversity of soft-bottom environments observed in Puget Sound.

Samples from 1997 have been analyzed and compared to the community parameters observed in the baseline samples taken from 1989 to 1993. Table 15 summarizes the community characteristics at these 10 stations and any differences observed in 1997. For three stations (Bellingham Bay, Port Gardner and Anderson Island), results from 1997 were generally consistent with the baseline findings. The other seven stations showed somewhat different conditions in 1997 than were observed previously. Changes at two stations (Point Pully and Strait of Georgia) indicated worsening conditions. Changes at one station (Commencement Bay) reflected improving conditions. Additional analysis is needed to understand whether the observed differences might reflect natural variability over the course of a few years or might point to other changes in the environment.

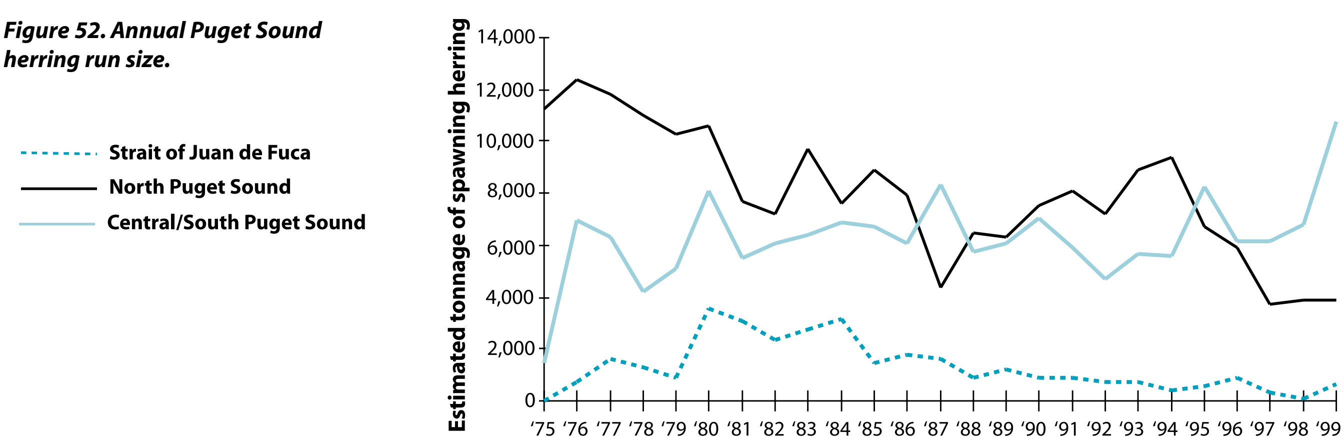
Fish

The condition or status of the various fish resources in Puget Sound exemplify why scientists who track the health of Puget Sound are concerned about the state of the estuary. Fish species in every grouping discussed in this section—forage fish, bottomfish and wild salmon—seem to be in serious decline in terms of population size, some enough to warrant review for possible listing as federally threatened or endangered species.

Pacific Herring. In June 1999, the National Marine Fisheries Service announced that it would conduct a "status review" of seven species of marine fish in Puget Sound to determine if they need protection under the federal Endangered Species Act. Pacific herring is among these seven species. Pacific herring is a vitally important forage fish species in Puget Sound and it is a significant resource for commercial and subsistence fisheries.

Figure 52 shows the estimated tonnage of spawning herring in north and south Puget Sound and the Strait of Juan de Fuca over the last 25 years. Stocks of herring in the north Sound and the Strait of Juan de Fuca have experienced a gradual, but fairly steady decline over the past 25 years. The status of the north Sound and Strait of Juan de Fuca stocks is currently depressed and critical. Stocks in south and central Puget Sound, on the other hand, do not show the same downward trends, and estimated herring run size has been increasing since 1996. Stock status for south/central Puget Sound is currently categorized as healthy.

Figure 52. Annual Puget Sound herring run size.



Source: Department of Fish and Wildlife.

Table 15. Summary of sediment-dwelling community characteristics at Ecology's long-term monitoring stations.

Station location (Station number)	Conditions represented by station	Summary of community character as observed from 1989-1993	Changes observed in 1997
Strait of Georgia (3)	Deep, mixed sand-silt-clay	Community unlike those at other monitoring locations; low abundance and numbers of species.	Symptoms of stress related to low dissolved oxygen —low abundance, diversity and species richness. Similar conditions observed in 1990, although diversity was not so low.
Bellingham Bay (4)	North Puget Sound clay	Relatively high numbers of species and diversity; community not dominated by any species.	Same as 1989-1993 baseline, except polychaete *Aricidea lopezi* now among the most abundant species.
North Hood Canal (13)	Sand	High abundance, moderate species numbers very low diversity. Dominated by the bivalve *Psephidia lordi*.	Large increase in abundance; small increase in number of species. *Phoronida* more abundant.
Port Gardner (21)	Mixed sand-silt-clay	Relatively high numbers of species and diversity; community not dominated by any species though most abundant species is an opportunistic bivalve.	Same as 1989-1993 baseline.
Shilshole (29)	Deep clay	Large cycles in abundance and species dominance. Dominated by the bivalve *Macoma carlottensis* and the ostracod *Euphilomedes producta*.	Abundance values below levels seen in 1992 and 1993; community appears to be less dominated by the most abundant species.
Point Pully (38)	Deep clay	Abundance is low, but numbers are increasing; community not dominated by any species.	Bivalve *Axinopsida*, which can indicate organic enrichment, now most abundant.
Sinclair Inlet (34)	Clay	High degree of dominance by two polychaetes, *Phyllochaetopterus prolifica* and *Aphelochaeta* sp.	Higher abundance but lower species numbers; no change in dominance.
Commencement Bay (40)	Silty sand or sand	Relatively high number of species and diversity; community not dominated by any species.	Higher abundance but no change in dominance. Community indicates improving conditions: *Aphelochaeta* disappeared, *Amphioda* now among most abundant species.
E. Anderson Island (44)	Sand	Relatively high numbers of species and diversity; community not dominated by any species.	Same as 1989-1993 baseline. Some shift in most abundant species, possibly resulting from the very evenly distributed community.
Inner Budd Inlet (49)	South Puget Sound inlet end, mud	Low abundance, number of species and diversity; in 1993, abundance spiked and the diversity was unusually low.	Community may be structured by episodes of low dissolved oxygen. Abundance and diversity returned to pre-1993 levels.

Source: Roberto Llansó, unpublished analysis of Department of Ecology data.

The combined herring run size for all stocks in Puget Sound was 15,300 tons in 1999. This was the largest total weight measured since 1995. The increase occurred mainly in south and central Puget Sound. Though the total Puget Sound estimate for 1999 was a substantial increase from 1998 numbers, it was still considerably lower than the 1980 peak estimate for herring run size of 22,200 tons. Further, overall status for all Puget Sound stocks was depressed in 1999. Department of Fish and Wildlife classified the 18 known stocks of herring in Puget Sound in 1999 as follows: seven stocks in healthy condition, three in moderately healthy condition, five depressed, two critical and one in unknown condition. The number of stocks in the depressed and critical categories more than tripled between 1994 and 1998.

Historically the largest of the 18 known herring stocks in Puget Sound, the Cherry Point stock of Pacific herring has declined a dramatic 91 percent over the last 25 years. This decline, coupled with a proposed pier extension at ARCO oil refinery facilities at Cherry Point led the Washington Department of Natural Resources to commission an ecological risk assessment of the project. This assessment revealed some interesting findings about the decline of the Cherry Point herring:

- Increasing mortality in the adult age classes accounts for much of the overall decline in the biomass of the stock.
- Because harvest pressures have declined over time, adult mortality must be due to other factors. Possibilities include increased predation and a variety of stressors linked to changing oceanographic conditions.
- The number of two and three year old spawners does not appear to have declined, further supporting the idea that the overall decline in the stock results from mortality in the older, rather than the younger, age classes.
- There is evidence that in contrast to the other Puget Sound stocks that appear to be resident, the Cherry Point stock is a migratory population that spends its summers and winters off the coast of Vancouver Island, making it subject to local conditions there as well.

The study concluded that local stressors do not seem to be the primary cause for the decline in the Cherry Point herring stock. Further, the study's review of individual stressors at Cherry Point found that their contribution to the decline in the stock would likely be negligible to low. The potential cumulative effect of stressors was difficult to assess due to a lack of available data.

Although the ecological risk assessment did not find habitat loss and toxicity to be among the primary causes of the historic decline in the abundance of Cherry Point herring, these factors have been identified as important to preventing further stock declines and to facilitating stock recovery. Agencies are now completing additional studies of potential stressors on herring in the Cherry Point area. Habitat loss due to development is a concern because the proposed pier extension affects one of the few remaining stretches of habitat that is currently being used by herring for spawning. Exposure to contaminants is also being evaluated because environmental contaminants from nearby industrial activities may affect critical life stages and impair the reproductive success of the Cherry Point stock.

Sand Lance and Surf Smelt. Sand lance and surf smelt are a significant part of the forage base for seabirds, marine mammals and a variety of fish in Puget Sound, including salmon. However, despite the critical role these forage fish play in the Puget Sound ecosystem, data are insufficient to support assessments of the status of these fish or to determine if stocks have been growing or declining in recent years.

Information regarding the biology and life history of both sand lance and surf smelt stocks within Washington is limited. Data collection has focused on the identification and documentation of spawning habitat, which occurs within the upper intertidal zone and is very susceptible to degradation from development. Department of Fish and Wildlife scientists have surveyed 75 percent of Puget Sound beaches for the two species, recording 135 miles of sand lance spawning habitat and 205 miles of surf smelt spawning habitat (Bargmann, personal communication). The spawning grounds for both species appear to be widely distributed throughout the shorelines of Puget Sound.

In 1998, in response to the important role of sand lance as forage and the lack of information on their abundance, the Washington Fish and Wildlife Commission ended all commercial fishing for the species. They also cut the daily limit for sport fishing of sand lance. Though the commercial fishery for surf smelt continues, the Fish and Wildlife Commission has reduced the sport fishing limit on this species. The Fish and Wildlife Commission took these actions in order to preserve the forage role of sand lance and surf smelt in the marine waters of Washington State.

Bottomfish. Bottomfish are marine fish species that live near or on the bottom of marine waters for most of their adult lives. Puget Sound once supported thriving commercial and recreational fisheries for bottomfish. However, many of these fish populations have recently declined to alarming levels. Some of these species have declined so much that the National Marine Fisheries Service received a petition asking that 17 species of Puget Sound bottomfish (in addition to Pacific herring) be considered as threatened or endangered under the federal Endangered Species Act. In June of 1999, the agency concluded that there was sufficient evidence to conduct a status review of six of the 17 bottomfish species included in the petition: Pacific cod, walleye pollock, Pacific whiting, copper, quillback and brown rockfishes. The National Marine Fisheries Service concluded that information was insufficient to support a status review for the other 11 species, all of which were rockfish.

The *1998 Puget Sound Update* included a summary of the findings of the Department of Fish and Wildlife's "1995 Status of Puget Sound Bottomfish Stocks" (revised as Palsson et al., 1997), which described the status and trends of 18 species or species groups of bottomfish. In their assessment of conditions in 1995, Fish and Wildlife scientists reported that the majority of bottomfish stocks were in below average or worse condition and that Pacific cod, walleye pollock and Pacific whiting were in critical condition.

Department of Fish and Wildlife scientists are currently updating their evaluation of the status of bottomfish in Puget Sound. Their assessment so far finds that the majority of bottomfish stocks are still in poor condition; accordingly, their status is below average, depressed or critical (Table 16, page 88). As with the 1995 assessments, most of the ongoing evaluation is based on information supplied by recreational or commercial fishers. The success of fishers over time provides an indication of the relative population strength for many bottomfish species. Assessments are conducted separately for fish in the northern part of Puget Sound (the straits of Juan de Fuca and Georgia and the San Juan Archipelago) and those in the southern part of the Sound (all of Puget Sound proper, the Whidbey basin and Hood Canal). At the time this document was prepared, scientists had only enough information to assess the status of 21 of the 39 species-stock combinations. The status of the remaining stocks was unknown. Eleven of the 21 stocks for which sufficient information was available (52 percent) were in poor condition. Seven of these stocks were identified as depressed and four were in critical condition. Three of the four stocks in critical condition were from the southern part of the region. Nine stocks, mostly in the northern area, were in average or above average condition. Scientists had the least information about stocks from south Puget Sound, where the status of 12 stocks is unknown.

Reasons for declines in bottomfish stocks

There is no single reason to explain the decline that has been observed in key bottomfish species in Puget Sound. A variety of potential stressors have been identified as likely contributors to depressed bottomfish species, including fishing, marine mammal predation, changes in regional climate and possibly toxic contamination, hatchery practices and nearshore land-use practices (West, 1997). For Pacific cod and walleye pollock, warm oceanic conditions most likely caused a natural decline in these cold water species. As with other species, additional stressors may have acted to further hasten their declines. In the case of cod and pollock, marine mammal predation and relatively intense fishing likely furthered the population decline. For Pacific whiting, the population was subjected to heavy fishing for a number of years before fishing was ended. However, the population continued to decline after the fishing ban as predation by sea lions appears to have intensified. For nearshore rockfish species, fishing appears to be the primary factor controlling population numbers and the sizes of individual fish (Palsson and Pacunksi, 1995).

Table 16. 1998 status of Puget Sound bottomfish stocks.

Species	North Sound	South Sound
Spiny dogfish	Depressed	Average
Skates	Above Average	Unknown
Spotted ratfish	Unknown	Unknown
Pacific cod	Depressed	Critical
Walleye pollock	Critical	Critical
Pacific whiting	Depressed	Critical
Rockfishes	Depressed	Depressed
Lingcod	Depressed	Above Average
Sablefish	Above Average	Unknown
Greenlings	Unknown	Unknown
Sculpins	Unknown	Unknown
Wolf-eel	Unknown	Unknown
Surfperches	Unknown	Average
English sole	Above Average	Unknown
Rock sole	Depressed	Unknown
Starry flounder	Above Average	Unknown
Dover sole	Above Average	Unknown
Sand sole	Above Average	Unknown
Pacific halibut	Above Average	Above Average
Other groundfish	Unknown	Unknown

Source: Washington Department of Fish and Wildlife (in preparation).

Several assessments have changed since 1995. Dover sole in the northern part of the Sound and surfperch in the southern part of the region have been upgraded from depressed or critical condition in the 1995 assessment to average or above average condition in the new assessment (Table 16). Spiny dogfish populations in the northern part of the region have shifted from average to depressed status since the 1995 assessment. The assessment for Pacific halibut in Puget Sound (part of the southern management region of the International Pacific Halibut Commission) changed from below average to above average.

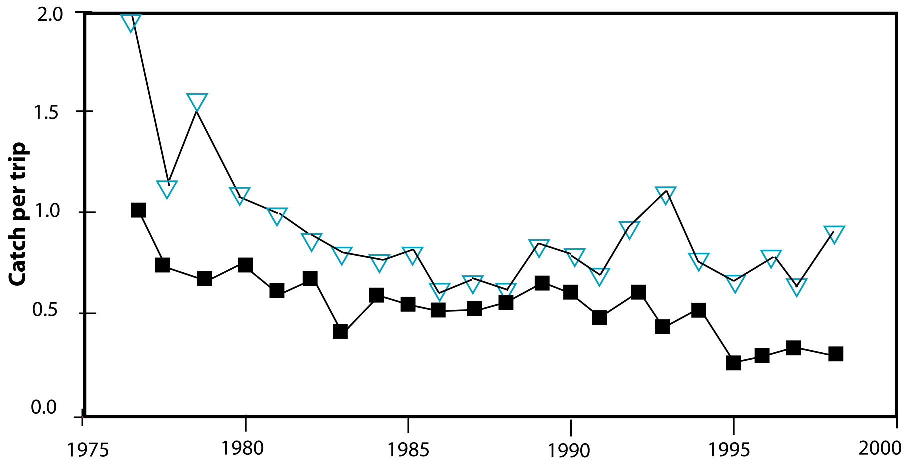
Rockfish assessments have been expanded to incorporate information on changes in size and estimated reproductive output for the most prevalent species. In both north and south Puget Sound, rockfish populations are now characterized as depressed. Rockfish stocks that were previously listed as average or below average have been downgraded to depressed based on a long-term decline in the success of rockfish catch by recreational fishers targeting bottomfish (see Figure 53) and by a decline in the proportion of large copper rockfish, a commonly harvested species, in the recreational catch (see Figure 54). Fish size is important because smaller fish are not able to produce as many eggs as larger fish. The smaller number of fish, which is indicated by the decline of the rockfish catch, and the smaller number of eggs per fish, which is indicated by the reduced size of individual fish, have combined to substantially reduce the estimated spawning potential of copper rockfish. Across the region, spawning potential has declined approximately 75 percent since the historic peak levels observed during the 1970s. Many management authorities consider declines of more than 60 percent of the natural spawning potential as a sign of a population under stress.

Fish and Wildlife's current assessment lists more stocks as unknown than did their 1995 assessment. This has happened primarily because the recreational fisheries are not providing sufficient data about some of the more uncommon species. Additional surveys and other sources of information will be needed to provide a means to evaluate the status of some of these poorly understood stocks.

Survey of fish species on the Washington/British Columbia border

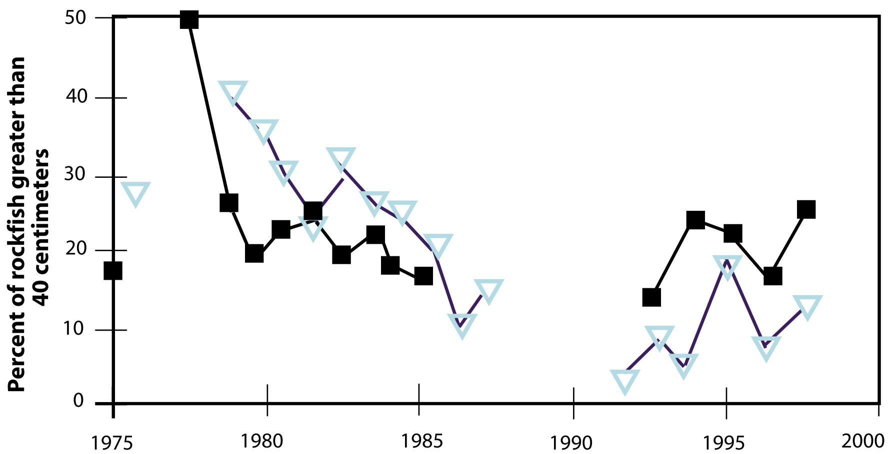
In 1997, Department of Fish and Wildlife scientists conducted a trawl survey in the transboundary waters of Washington and British Columbia in the southern Strait of Georgia. The survey had four broad goals: to estimate the abundance of key benthic (bottom-dwelling) fish species; to identify population trends; to quantify the impact of fisheries on fish stocks; and to determine the distribution of key commercial fishes that likely move across the international boundary. The study revealed several findings:

- British Columbia has a greater number of fish species and individuals in the area sampled, which reflects the distribution of habitat between the province and Washington State. The spotted ratfish is dominant in both regions.
- Key shallow-water fish species are restricted by the deep waters of the central basin and are less likely to make transboundary movements. This forces Washington and British Columbia to fish particular stocks in their own waters. The deepwater species, on the other hand, are more likely to move across the international border. This subjects them to both Washington's and British Columbia's fisheries.
- Washington fisheries have a greater impact overall on fish stocks in the Strait of Georgia than do British Columbia fisheries. Washington fisheries harvest a greater proportion of the stock of key commercial species. Further, Washington fisheries appear to be benefiting from the transboundary movements of deepwater species, especially spiny dogfish. For the shallow-water species, both British Columbia and Washington fisheries may be significantly impacting localized stocks.



Source: Department of Fish and Wildlife.

Figure 53. Success of rockfish catch by recreational bottomfish fishers.



Source: Department of Fish and Wildlife.

Figure 54. Large copper rockfish in recreational catch.

Coho Smolt Production and Marine Survival. Since the 1970s, the Department of Fish and Wildlife has measured wild coho smolt production from a number of Puget Sound watersheds. Results of this long-term monitoring project explain inter-annual variation in production. A number of factors, such as flow conditions during critical periods throughout the year, spawner escapement, habitat damage and interactions with other species, affect smolt production. Variations in coho smolt production for three Puget Sound rivers are summarized in Table 17. Over the years measured, coho smolt production in Big Beef Creek, a small stream on Hood Canal, varied by a factor of four and smolt production in the Skagit River varied by a factor of three. Coho smolt production in the Deschutes River (the southernmost tributary to Puget Sound) varied by a factor of more than 20.

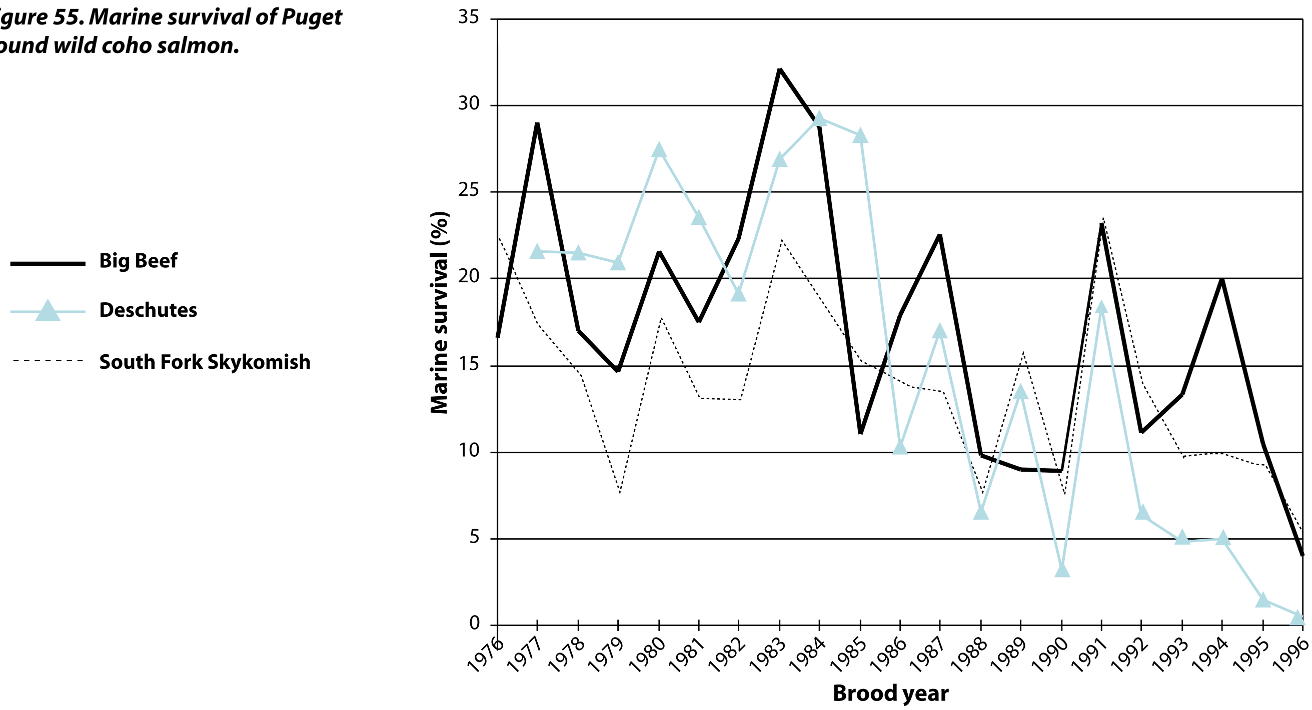
The Deschutes River system once produced an average of 70,000 wild coho smolts. As recently as 1990, the river produced as many as 133,000 smolts. More recently, however, production in the Deschutes River has declined to less than 10,000 wild coho smolts. Habitat damage in the upper watershed, small body-size of returning adults, high flows during egg incubation and most importantly, extremely low marine survival throughout most of the 1990s, appear to be responsible for this decline. Department of Fish and Wildlife scientists measured marine survival rates for wild coho stocks at several stations in Puget Sound beginning as early as 1979. For more than 12 brood years from 1976 through 1987, wild coho smolts survived to become

Table 17. Puget Sound coho smolt production.

Stream (period of record)	Low Production	High Production	Average Production	1998 Production
Big Beef Creek (21 years)	11,500	45,634	24,614	22,000
Deschutes River (19 years)	6,000	133,198	66,000	6,000
Skagit River (9 years)	617,600	1,760,000	1,002,000	1,760,000

Source: Department of Fish and Wildlife.

Figure 55. Marine survival of Puget Sound wild coho salmon.



Source: Department of Fish and Wildlife.

adults at rates that averaged in excess of 20 percent. Marine survival declined in the early 1990s; over the eight broods from 1988 through 1995 (adults returning in 1991 through 1998, respectively), marine survival declined to an average of around 10 percent (Figure 55).

In recent years, coho stocks entering the south Puget Sound have experienced the lowest survival rates ever measured. Marine survival of Deschutes River wild coho, which enter Budd Inlet at Olympia, has declined more than any of the other stocks measured. Hatchery coho in the south Sound have also experienced extremely poor survival in recent years. For example, two million smolts released from Squaxin Island net pens in 1998 returned at just a fraction of one percent in 1999. The low survival rate affecting south Sound stocks appears to be occurring inside Puget Sound rather than in the ocean, based on survival trends for the other production areas.

Marine Birds and Waterfowl

Department of Fish and Wildlife scientists conducted PSAMP aerial surveys for marine birds from 1992 to 1999. These surveys covered 13 to 15 percent of Puget Sound's nearshore habitat (waters less than 20 meters deep) and three to five percent

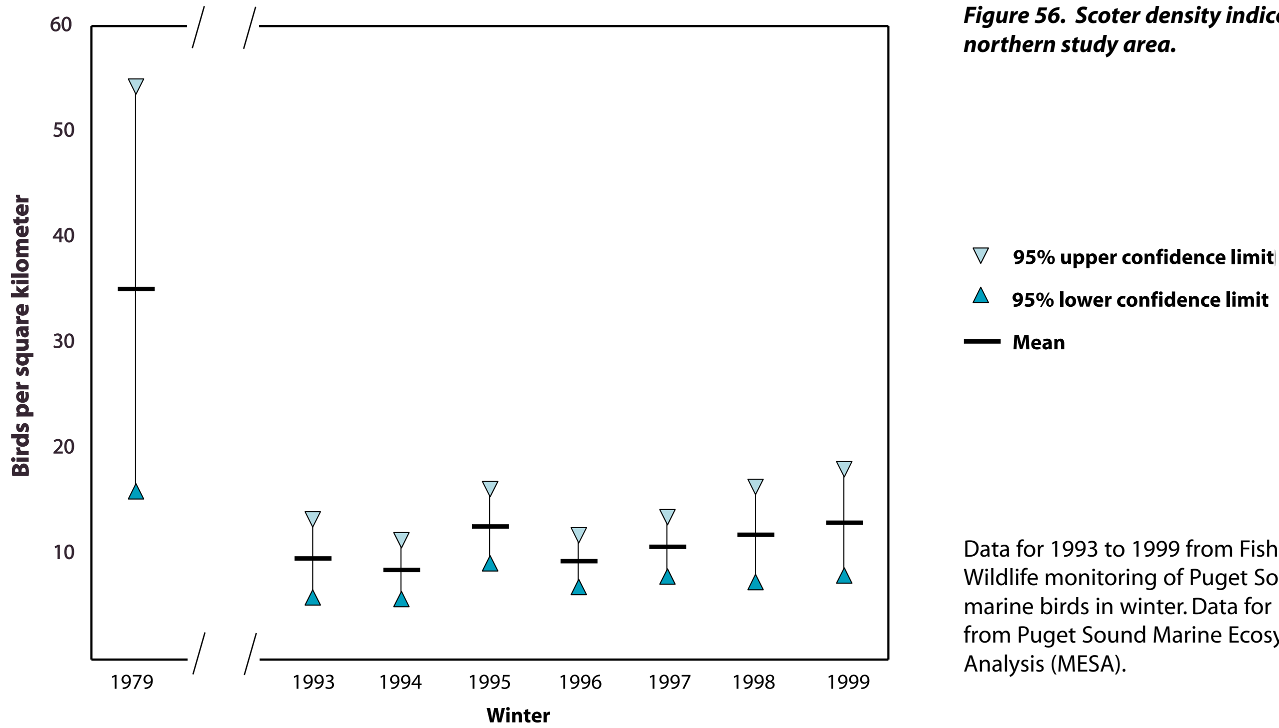


Figure 56. Scoter density indices—northern study area.

Data for 1993 to 1999 from Fish and Wildlife monitoring of Puget Sound marine birds in winter. Data for 1979 from Puget Sound Marine Ecosystem Analysis (MESA).

of the Sound's offshore habitat (waters more than 20 meters deep) annually. The surveys were designed for monitoring the abundance and distribution of medium to large diving marine birds or waterfowl that use greater Puget Sound for some key portion of either the summer (July) or the winter (December-February). As a result of the surveys, habitat and geographic usage patterns have been well-documented for a variety of species. The surveys also provided information on changes and trends in abundance over time. This *Update* presents survey results through winter 1999 for scoters (primarily surf and white-winged scoters) and western grebes. These two species groups were selected for reporting because survey results for these birds, more than most other species, indicated that densities observed in the 1990s were lower than those observed in the late 1970s. Results from an intensive boat-based survey of pigeon guillemots in 1999 are also provided. In addition, the status and trends in the numbers of American widgeons and Harlequin ducks are discussed based on studies conducted outside of the PSAMP.

Scoters. Fish and Wildlife scientists have previously presented data that showed that wintering scoter numbers in greater Puget Sound have declined by between 40 and 70 percent over the last 20 years (Nysewander and Evenson, 1998). Figure 56 presents scoter densities observed in various years for the Strait of Juan de Fuca, the San Juan Islands and the marine waters north to British Columbia. During the PSAMP monitoring effort from 1992 to 1999, which focused on all of the inland marine waters of Washington, scoter densities were either relatively stable or decreasing slowly. Year-to-year variations in density were consistent in the north and south portions of the survey area except during winter 1996-97 (Figure 57, page 92). That winter, the scoter density decreased in the southern part of the survey area but increased in the northern part. Results from the next two winters were consistent with the 1996-97 findings, indicating a slight shift in scoter densities from south to north compared to earlier years. Even after this increase in scoter densities in the north, the southern portion of the survey area (which includes south and central Puget Sound) contained both higher densities and higher overall numbers of scoters than those areas supporting scoters in the north.

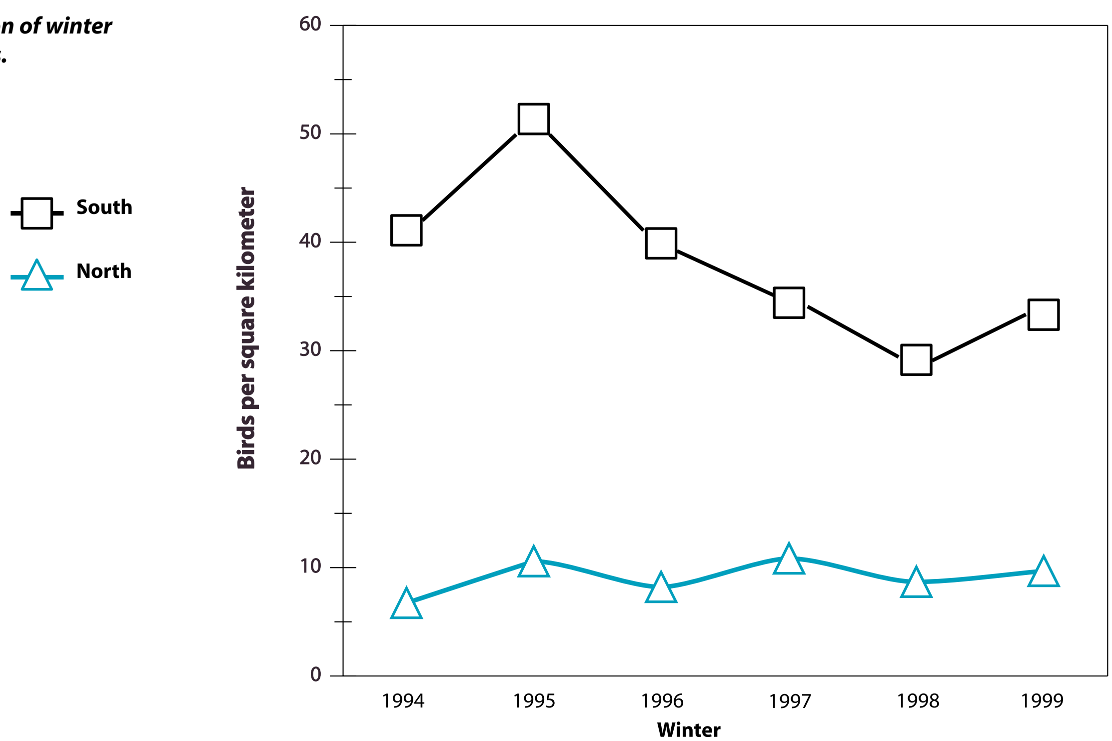
Because changes in annual density indices can vary by degree and direction in any one year between different portions of Puget Sound, it is useful to revisit whether scoters are moving to some other portion of their wintering range rather than disappearing. Nysewander and Evenson (1998) reviewed conditions at all other wintering areas on the west coast from which data were available and observed that all had declining numbers of scoters over the last 20 years. The data did not suggest that disappearing scoters were moving from one wintering area to another. However, British Columbia marine waters are not monitored in the winter for sea ducks. It is possible that scoter densities may have increased in British Columbia while they have decreased elsewhere.

Western Grebes. Western grebe populations appear to have declined even more over the last 20 years than scoter populations. Wahl et al. (1981) reported that 38,000 western grebes were present in greater Bellingham Bay in 1978-79. PSAMP aerial surveys have never recorded more than 5,700 birds in that area between 1993 and 1999.

Estimates of western grebe numbers in Puget Sound are imprecise because the clumped distribution of these birds introduces considerable uncertainty in numbers derived from any given survey. Note, for example, the large variability seen in the winter of 1996-97 (see Figure 58). Nevertheless, survey data shown in Figure 58 suggest that western grebe populations have declined at least 50 percent or more over the last 20 years. Figure 59 shows that the southern portion of the survey area (south and central Puget Sound) had both higher densities and higher overall numbers of western grebes than the areas to the north in recent years. As with scoters, the lack of winter monitoring in the more protected marine waters of British Columbia limits the ability of scientists to evaluate possible movement of grebes over the years and to estimate the overall size of the wintering population in the region's marine waters.

Pigeon Guillemots. Pigeon guillemots are numerous, well-distributed, year-round residents of Washington's inland marine waters. Two sets of historical data exist regarding pigeon guillemots in Puget Sound: 1) northern Puget Sound summer aerial surveys taken during the winter of 1978-79, and 2) June and July colony counts

Figure 57. Comparison of winter scoter density indices.



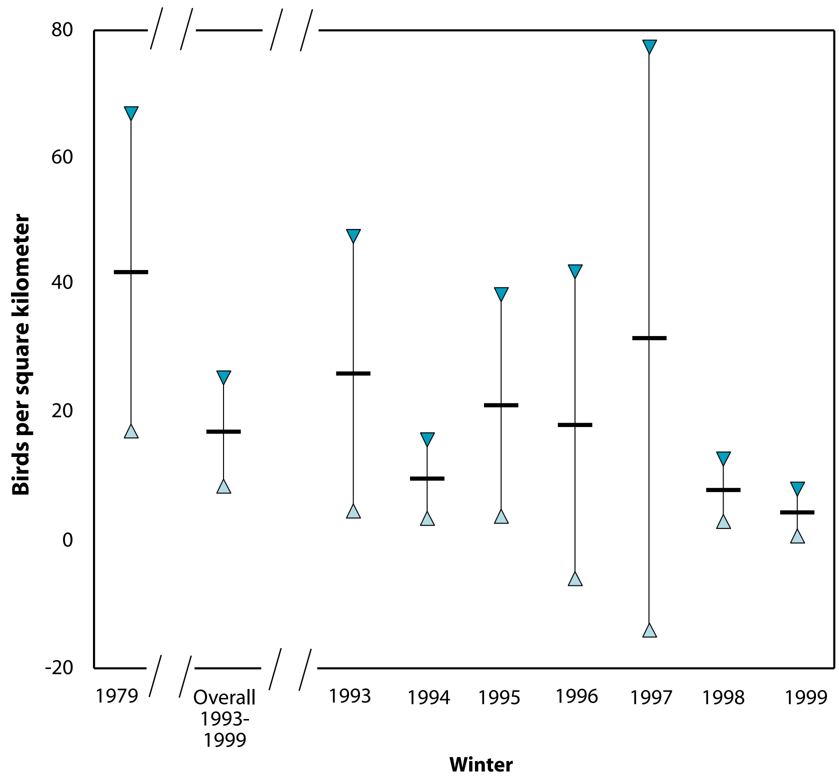


Figure 58. Western grebe density indices—northern Puget Sound study area, winter.

95% upper confidence limit

95% lower confidence limit

Mean

Data from 1993 to 1999 from Fish and Wildlife monitoring of Puget Sound marine birds in winter. Data for 1979 from Puget Sound Marine Ecosystem Analysis (MESA).

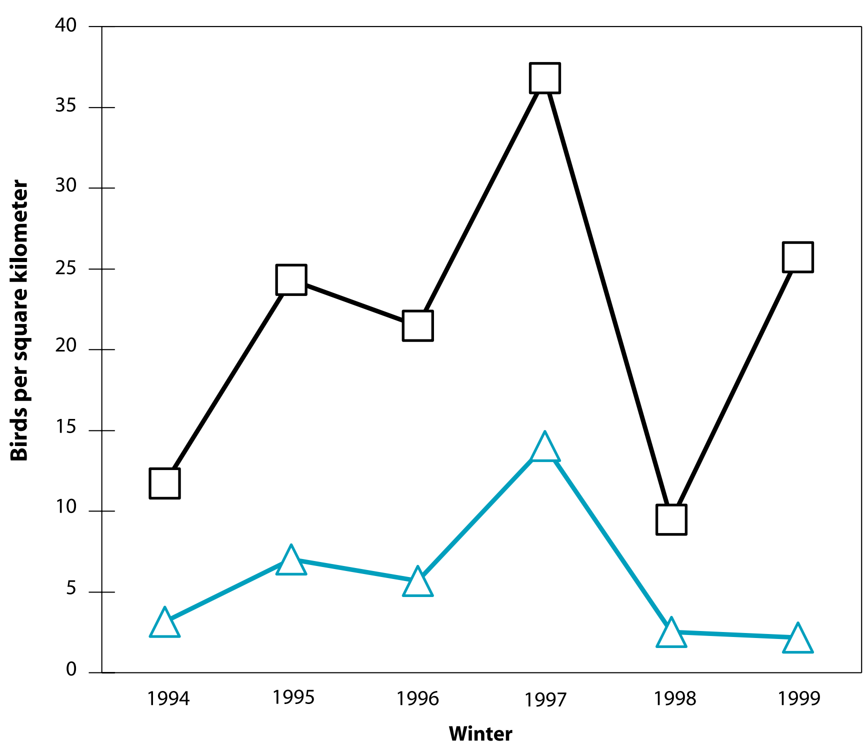


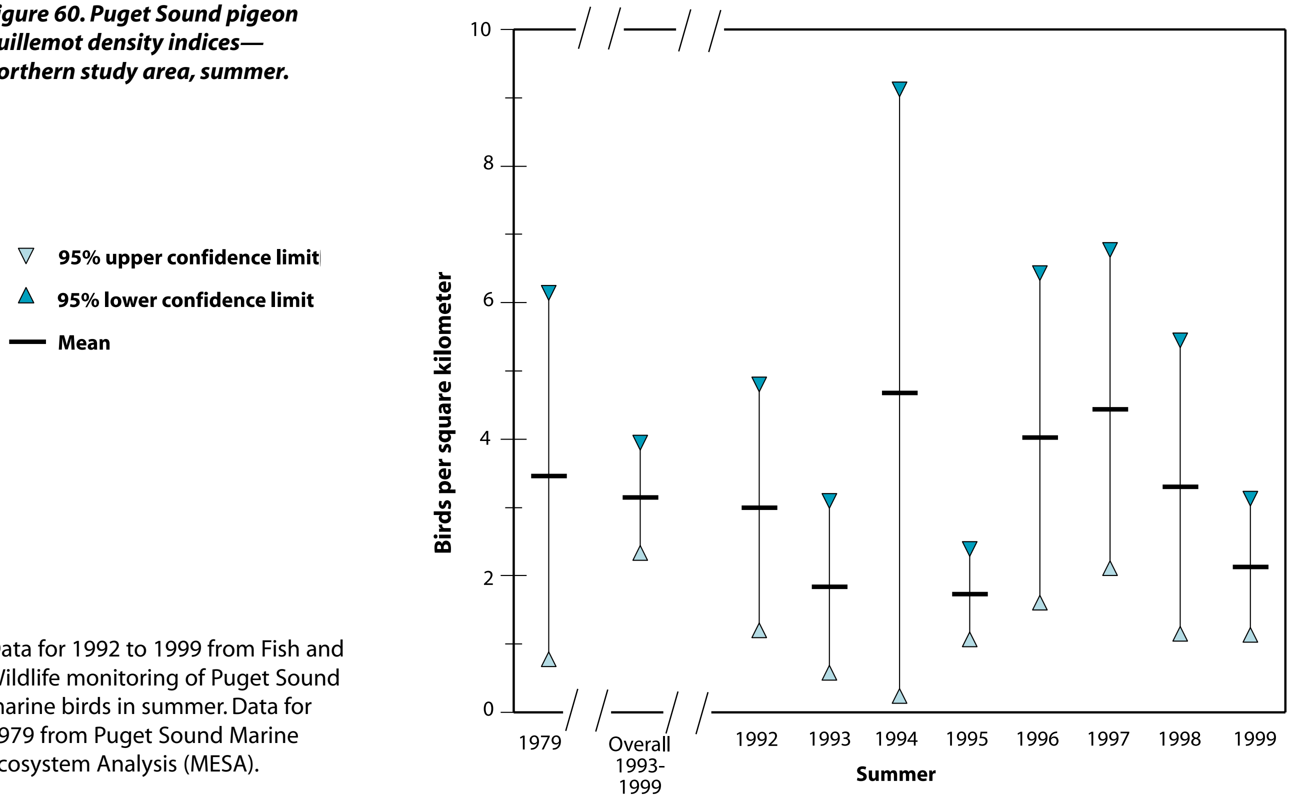
Figure 59. Comparison of western grebe density indices.

South

North

Data from Fish and Wildlife monitoring of Puget Sound marine birds.

Figure 60. Puget Sound pigeon guillemot density indices—northern study area, summer.



Data for 1992 to 1999 from Fish and Wildlife monitoring of Puget Sound marine birds in summer. Data for 1979 from Puget Sound Marine Ecosystem Analysis (MESA).

conducted prior to 1983 (Speich and Wahl, 1989). More recently, Fish and Wildlife scientists monitored pigeon guillemots in Puget Sound during the PSAMP summer aerial surveys from 1992 to 1999. It is difficult to compare guillemot densities derived from the PSAMP surveys with estimates from the 1978-79 northern Puget Sound surveys because of the large uncertainty associated with each density estimate (see Figure 60).

To obtain a clearer picture of the pigeon guillemot population in Puget Sound, a breeding colony census was coordinated by PSAMP program staff working at the Washington Department of Fish and Wildlife and staff from the U.S. Fish and Wildlife Service's western Washington office in May and June 1999. The participants in the surveys included staff from these coordinating groups, staff from the National Wildlife Refuges and the Whale Museum, and regional staff from state Fish and Wildlife. The 1999 pigeon guillemot colony census resulted in counts of guillemots at 367 colonies within Puget Sound, 120 of which were previously catalogued colonies and 247 of which were identified in the 1999 search effort but had not been previously catalogued (see Table 18). A total of 10,600 breeding pigeon guillemots were counted in 1999 from all colonies. Table 18 shows that the biggest gaps in the historical data were in the southern half of Puget Sound, where the 1999 census counted four times as many breeding birds as were counted in the previous listing.

The 1999 colony census data, based on early morning counts, are not directly comparable to the historical data from 1978 to 1982, which were based on counts conducted at various times throughout the day. One would expect that the difference in methodology would result in higher counts in 1999 (because more birds are typically present at their colonies in early morning). Comparisons of counts at 58 colonies surveyed from 1978 through 1982 and again in 1999 showed relatively small differences. Eleven percent more birds were counted at 45 colonies in the northern half of Puget Sound. Two percent more birds were counted at 13 colonies in the southern half of Puget Sound. These results suggest that numbers of pigeon

	Colonies Previously Listed		Colonies Not Previously Listed		All Colonies	
Region	Number of Colonies	Count of Guillemots	Number of Colonies	Count of Guillemots	Number of Colonies	Count of Guillemots
North >Lat 48°N	91	6,262	121	2,429	212	8,691
South <Lat 48°N	29	478	126	1,464	155	1,942
Total	**120**	**6,740**	**247**	**3,893**	**367**	**10,633**

Table 18. Pigeon Guillemot colony counts from the inland marine waters of Washington State.

Counts at colonies previously listed in the *Catalog of Washington Seabird Colonies* were conducted during May 1999. Counts at colonies not previously listed in the catalog were conducted during May and June 1999.

guillemots have not declined as have scoters and western grebes. However, future surveys using the standardized methodology implemented in 1999 will be needed to better evaluate trends in pigeon guillemot numbers in Puget Sound.

American Widgeons at the Nisqually National Wildlife Refuge. The Nisqually Delta, located at the southern end of Puget Sound, is a major non-coastal resting and feeding area for migrating waterfowl and shorebirds within the Pacific flyway. Nisqually National Wildlife Refuge (U.S. Fish and Wildlife Service) staff have conducted fall and winter aerial surveys (October through March) over the Nisqually Delta to monitor waterfowl populations since 1975.

Dabbling ducks accounted for more than 90 percent of all waterfowl sightings in these surveys. American widgeon, the most abundant dabbling duck species observed on the refuge, made up 71 percent of all dabbling ducks sighted. The American widgeon spends more time in marine waters than other dabbling ducks; American widgeons that winter locally spend an average of eight months of the year in Puget Sound. Approximately 20,000 widgeons were observed on two occasions (October 1979 and November 1982). All other counts from 1975 to 1998 were below 15,000. Between 1995 and 1998, peak numbers of widgeons ranged from only 870 to 9,110, representing a drop of 55 percent or more since the peak observed in 1982. (The lowest count, 870 birds, occurred in 1997, when only one survey was conducted for the entire season. A peak count very well may have been missed for that year.)

Figure 61 presents annual peak observations and suggests a downward trend in widgeon numbers at the Nisqually Delta. However, there is high variability in peak counts, the trend is not statistically significant. Nonetheless, the dramatic decline in the number of widgeons observed to be using the Nisqually Delta over the last five

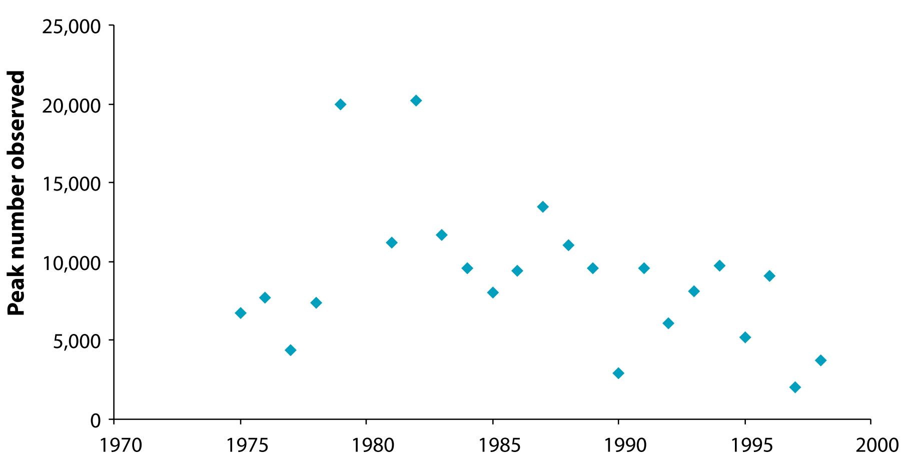
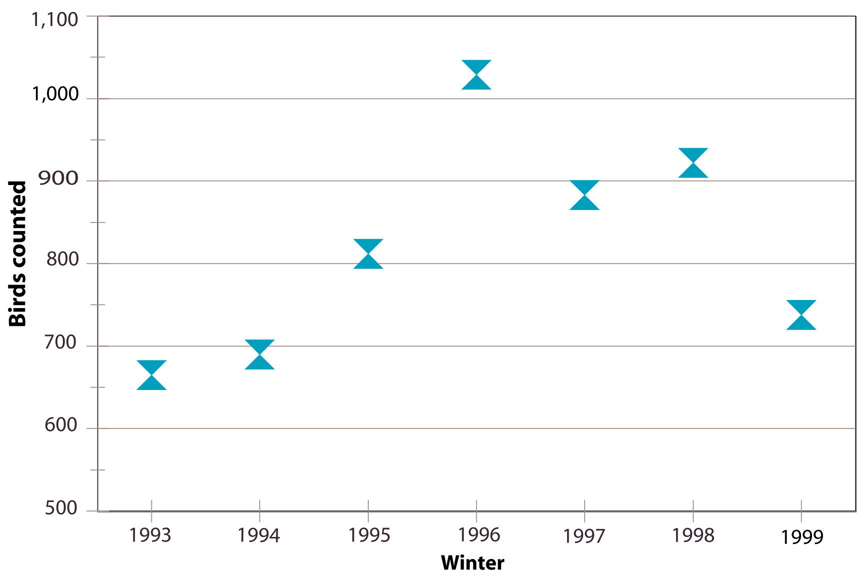


Figure 61. Annual peak American widgeon counts, Nisqually Delta. 1975-1998.

Source: Nisqually National Wildlife Refuge, U.S. Fish and Wildlife Service.

Figure 62. Harlequin duck trends for Puget Sound, PSAMP winter surveys.



years warrants further investigation. In addition, waterfowl surveys conducted throughout Puget Sound might be evaluated to investigate trends in American widgeon numbers elsewhere in the Sound.

Harlequin Ducks. Department of Fish and Wildlife biologists have worked with scientists from other states and provinces to gain a better understanding of the ecology and status of harlequin ducks. Harlequin ducks nest along fast moving mountain streams throughout the mountainous West. They return to the saltwater to molt, select a mate and forage for the winter. They concentrate primarily in exposed rock, cobble and kelp habitats throughout the Strait of Juan de Fuca and the Georgia Basin. Department of Fish and Wildlife winter aerial surveys were conducted throughout Puget Sound and the outer coast from 1991 to 1997 to track population trends. Analysis of data from selected areas within these surveys suggest that Washington's harlequin duck population increased from 1991 to 1997. Total counts of harlequin ducks from the 1993 to 1999 PSAMP winter aerial surveys in greater Puget Sound show this increase, but also show subsequent decreases in numbers from 1996 to 1999 (Figure 62). This Sound-wide decrease was largely attributable to decreases in harlequin numbers at Protection Island, which recently lost the considerable kelp beds that were present there earlier in the decade (see page 82).

With the help of volunteers who observed marked harlequins (see sidebar), Department of Fish and Wildlife biologists estimated the overall peak population in Washington waters during the late summer to fall of 1997 at 2,384 +/- 282 ducks. The survival and recruitment rates for males were calculated at 0.78 and 0.39, respectively. These numbers suggest a stable population of harlequin ducks wintering in the marine waters of Washington State.

Although the Washington State population of harlequin ducks appears to be stable, it is relatively small. Because most of the harlequin molting areas in Washington are in the straits near tanker routes, this relatively small population is vulnerable to oil spill impacts and should be carefully monitored.

Harlequin ducks that winter in Puget Sound

Department of Fish and Wildlife studies of harlequin ducks have focused on five major molting sites in Puget Sound where the birds replace their worn flight feathers. During August and September, when the birds return to Puget Sound, they undergo a molt and are flightless for a period of time. Department of Fish and Wildlife scientists have captured and marked 805 harlequin ducks at the molting sites to study their movements to breeding grounds and to examine population demographics. The marked birds have been observed on nesting streams in Jasper, Banff and Grand Teton national parks, in northern Idaho and as far away as Hudson Bay. There appears to be little or no interchange with the large Alaskan population of harlequin ducks. Washington breeding harlequins have been observed wintering in the Strait of Georgia at Hornby Island.

Hood Canal Bald Eagles

The Department of Fish and Wildlife and the U.S. Fish and Wildlife Service continue to evaluate the status of bald eagles on Hood Canal, as reported in the *1998 Puget Sound Update.* It has been proposed that bald eagles be taken off the federal

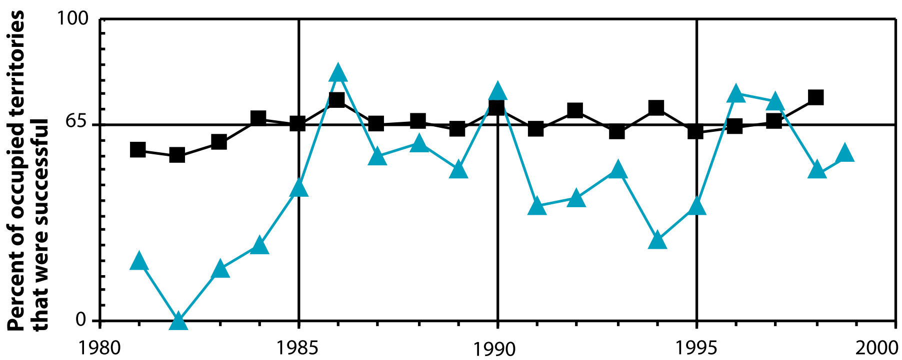


Figure 63. Nesting success of bald eagles in Hood Canal and statewide.

Source: Department of Fish and Wildlife.

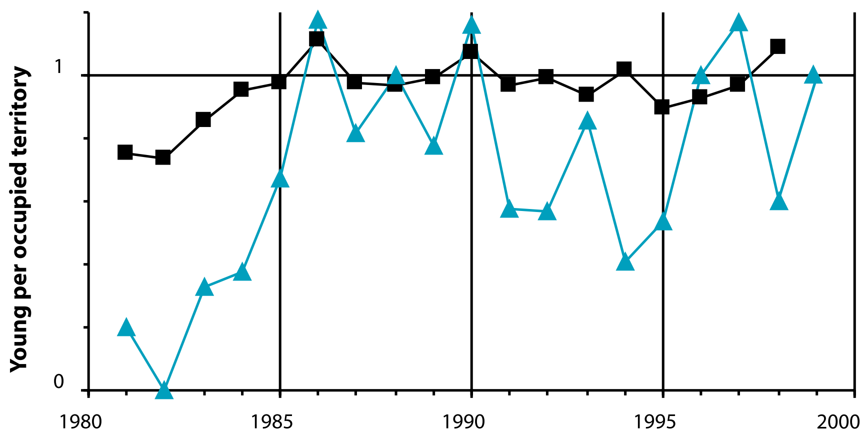


Figure 64. Young bald eagles per nest in Hood Canal and statewide.

Source: Department of Fish and Wildlife.

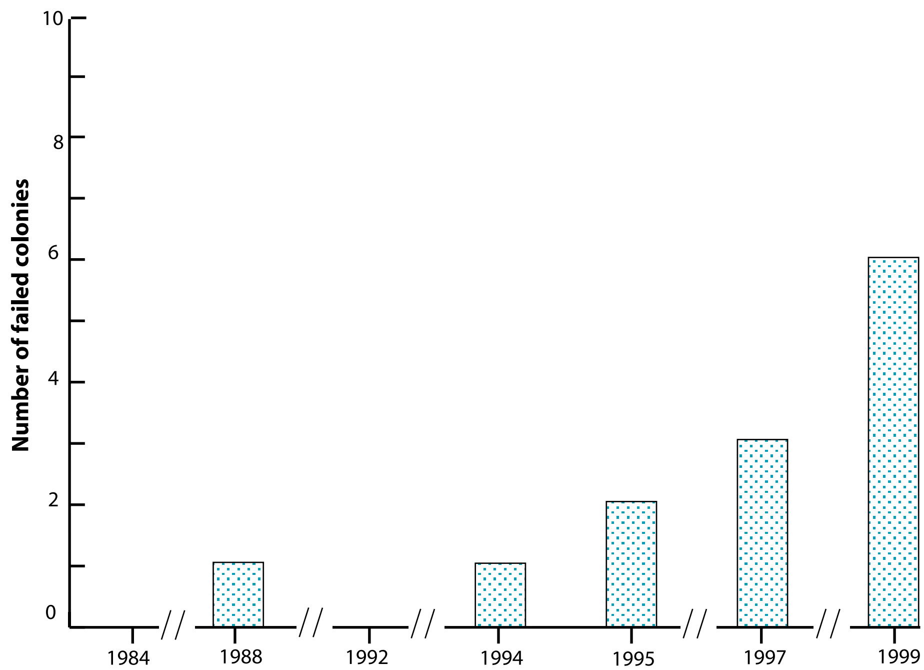
Endangered Species List. However, until the proposal is finalized, the bald eagle retains its federal status as a threatened species in Washington State. The Hood Canal population of bald eagles has at times exhibited very low productivity.

The Pacific State Bald Eagle Recovery Plan recommends that there be a five-year average of 1.0 fledgling per occupied nest and an average nesting success of 65 percent for the species to be removed from the Endangered Species List. Hood Canal eagles showed short-term positive trends and met both of these criteria in 1996 and 1997—better than bald eagles statewide. However, Figures 63 and 64 show that in 1998 neither of the criteria were met and, in 1999, only one of the criteria was met. Further, 1998 statewide bald eagle population and productivity numbers were better than Hood Canal numbers for the first time since 1995. The statewide data are not yet complete for 1999.

It is difficult to explain the variable success of Hood Canal bald eagles in recent years. Though toxic contaminants were cited as the primary reason for the decline of bald eagles at the time of listing, more study of contaminants in the Hood Canal food web would be needed in order to document whether contaminants currently threaten eagle production in Hood Canal. Other possible impacts on productivity of Hood Canal bald eagles include adverse weather conditions during critical incubation, human disturbance during the breeding and nesting season, predation of eggs or chicks and inadequate food supply.

Figure 65. Number of 10 major great blue heron colonies on Puget Sound abandoned by year.

No data available for years not shown (1985-1987; 1989-1991; 1993; 1996; 1998)



Source: D. Norman.

Great Blue Heron Colonies

The Audubon Society's Christmas Bird Count and data collected for the U.S. Fish and Wildlife Service show that great blue heron populations in Puget Sound began dramatically increasing in the 1960s. As of 1995, heron populations in the Sound were reported as stable (Norman, 1995). Recent data, however, show a negative trend in population size (Norman, personal communication).

A significant contribution to the recent decline in heron productivity is attributed to disturbance by bald eagles (Norman, personal communication). Eagle incursions into heron colonies have become commonplace, threatening the productivity of all heron colonies in western Washington. When eagles harass incubating herons, the herons temporarily abandon the nest, allowing crows to scavenge the eggs. After several such events, the herons abandon the colony.

In 1999 only a few colonies were spared harassment by eagles. Six of 10 colonies that had been monitored for more than 15 years were abandoned in 1999 (Figure 65). In addition, colonies at Port Orchard and Duckabush were abandoned. This pattern of colony abandonment puts the Washington heron population in an unstable condition.

Other factors that potentially threaten the heron population in Puget Sound include colder than normal winter conditions; exposure to toxic contaminants through food; and development that destroys foraging areas, alternate nesting sites and upland wintering areas.

Great blue herons and contaminated areas

In 1997, U.S. Fish and Wildlife Service scientists conducted a study to better understand the link between great blue heron productivity and foraging in potentially contaminated areas of Commencement Bay. Based on observations in the spring and summer of 1997, a Fish and Wildlife scientist (Krausmann, 1999) concluded that:

- Substantial numbers of herons' forage trips from Dumas Bay and Hylebos Waterway colonies (47 percent and 44 to 71 percent , respectively) were to Commencement Bay sites;
- The Dumas Bay colony failed, most probably the result of continuous harassment by bald eagles from February through May; and
- The Hylebos colony provided no evidence of a correlation between nest failure and selection of foraging locations; very few nests failed and most birds foraged in Commencement Bay.

Marine Mammals

Harbor Seal Populations. Surveys of harbor seal populations in Puget Sound began in 1978 and have continued as part of the PSAMP since 1985. Systematic surveys of Washington's inland marine waters have documented an increasing harbor seal population, with an estimated 16,000 seals present in 1997 (Washington Department of Fish and Wildlife (WDFW) and Northwest Marine Mammal Lab (NMML), unpublished data).

Overall growth of the harbor seal population in Washington's inland waters is estimated at 6.6 percent annually since 1978 (WDFW and NMML, unpublished data). Counts of seals hauled out at selected monitoring sites within Washington's inland waters reflect varying population growth rates (Figure 66, page 100) and indicate an apparent slowing of population growth in some regions. This slowing population growth suggests that the harbor seal population may have reached the limits of what Puget Sound can support.

Food Habits of Harbor Seals in Hood Canal

Fish and Wildlife scientists analyzed the food habits of harbor seals in Hood Canal by collecting and examining fecal samples (scats). Scats were examined for evidence of prey based on the occurrence of hard parts (i.e., otoliths, bones, teeth, squid beaks, etc.). Scats were collected at harbor seal haul-out areas near Quilcene Bay and the Dosewallips, Duckabush, Hamma Hamma and Skokomish rivers from September through November 1998. Based on the frequency of occurrence in scats (Table 19, page 100), Hood Canal harbor seals appear to eat a variety of prey. The most important species in their diet are Pacific hake, Pacific herring and salmon (WDFW, unpublished data).

Orcas (Killer Whales). Until 1995, the population of resident orcas (killer whales) in Puget Sound was increasing. Since 1995, however, this population of orcas, known as the "southern residents" of the inland marine waters of Washington and British Columbia, has decreased from 96 to 84 animals (Balcomb, personal communication). Scientists have recently reported highly elevated levels of PCBs in the whales (Ross et al., in press); some scientists suspect that these compounds may play a role in the observed population decline. A diminished food supply in the form of dwindling salmon populations and stress inflicted by heavy boat traffic are among the other possible contributors to declining orca numbers. As a result of the apparent decline and instability of the southern resident orca population, Washington biologists are preparing a petition to list the southern resident orcas as threatened or endangered under the federal Endangered Species Act.

Canadian biologists at the Pacific Biological Station, Department of Fisheries and Oceans Canada, have been collecting orca data since 1972. In contrast to the southern residents, the northern resident orcas, which live near the northern end of Vancouver Island, appear to be faring well overall. Their total population is approximately 210 individuals. Canadian scientists developed a population model in 1990 that showed that the northern resident population of orcas had been increasing at a steady rate of two to three percent per year. Another version of this model, based on data collected since 1990, is currently under development.

Aquatic Nuisance Species

Exotic species have been introduced to marine waters through shipping, aquaculture and other human activities. While awareness of the threat of exotic species is becoming widespread, current research has focused on tracking and controlling several species of concern, including the cordgrasses, *Spartina* spp., and the green crab, *Carcinus maenus.* These species and their undesirable effects on the ecosystem are comparatively well understood. In contrast, most other non-indigenous (exotic) species in Puget Sound are little recognized and poorly known.

The impacts of an exotic species moving into and becoming established into a new ecosystem are difficult to predict; while the effects of many non-indigenous species can go unnoticed, others can be catastrophic. For example, an introduced Atlantic shipworm bored its way through the entire maritime infrastructure—wharves, piers and ferry slips—causing more than $2 billion in damage in northern San Francisco

Harbor seals in the Pacific Northwest

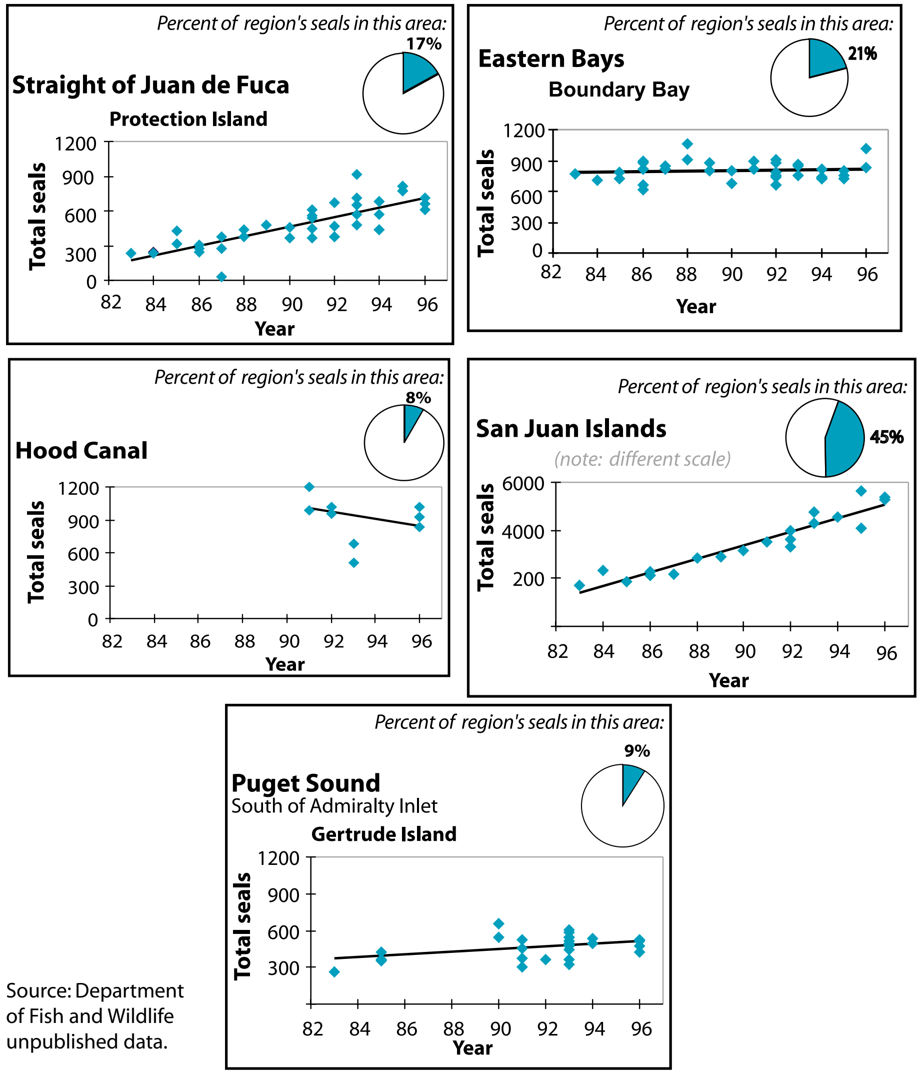
Harbor seals are the most abundant marine mammal in the Pacific Northwest, with approximately 35,000 resident in Washington. Historical levels of their abundance are unknown, but numbers were severely reduced in prior years by bounty and other control programs that aimed to reduce competition between seals and commercial and sport fishermen. The Washington State harbor seal population was estimated at 2,000 to 3,000 animals in the early 1970s. Since the Marine Mammal Protection Act (MMPA) was passed in 1972, harbor seal numbers in the Pacific Northwest have shown significant increases.

Impacts of harbor seals and California sea lions on West Coast ecosystems

In February 1999, the National Marine Fisheries Service issued a report entitled "Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and West Coast Ecosystems." This report addresses the potential impact of abundant and increasing seal and sea lion populations and resulting predation on salmonid species that are on the decline or are listed under the federal Endangered Species Act (ESA). It also addresses impacts to other ecosystem components and to human activities. While seals and sea lions are protected under the Marine Mammal Protection Act of 1972, the report recommends that declining or ESA-listed salmonid species should be given precedence over seals and sea lions (on a site-specific basis) when conflicts between the protected species arise.

Figure 66. Numbers of harbor seals in Puget Sound. Percent of seals by region in 1996 and at representative survey locations, 1983-1996.

Note: Trend lines indicate a best-fit linear relationship, but do not indicate statistical significance.



Source: Department of Fish and Wildlife unpublished data.

Table 19. Frequency of occurrence of prey species in harbor seal scats collected in Hood Canal, Fall 1998.

Prey species	Percent occurrence of prey species in scat samples
Pacific hake *(Merluccius productus)*	84.8
Pacific herring *(Clupea harengus)*	43.7
Salmon *(Oncorhynchus* species)	25.4
Shiner surfperch *(Cymatogaster aggregata)*	6.6
Squid *(Loligo* species)	3.4
Pacific staghorn sculpin *(Leptocottus armatus)*	2.7
Pacific tomcod *(Microgadus proximus)*	2.5
Plainfin midshipman *(Porichthys notatus)*	2.4
Northern anchovy *(Engraulis mordax mordax)*	2.4
Juvenile crab (infraorder Brachyura)	1.7
Threespine stickleback *(Gasterosteus aculeatus)*	1.2
Other species*	3.2
Unidentified fish	4.9

Based on analysis of 591 scats from Quilcene Bay and the Dosewallips, Duckabush, Hamma Hamma and Skokomish rivers.

**Other prey species (less than 1.0 percent) include pile perch* (Rhacochilus vacca)*, English sole* (Parophrys vetulus)*, rockfish* (Sebastes spp.)*, walleye pollock* (Theragra chalcogramma)*, Berryteuthis species, roughback sculpin* (Chitonotus pugetensis)*, surf smelt* (Hypomesus pretiosus pretiosus) *and skate (Family Rajidae)*

Bay in 1919 and 1920 (after it was first noticed in the bay in 1913). Although they are often more difficult to assess, the ecological impacts of exotic species can be severe.

The Puget Sound Expedition: A Systematic Survey for Exotic Species. To provide improved baseline information on non-indigenous species in Puget Sound, Department of Natural Resources scientists jointly organized the Puget Sound Expedition, a systematic survey of exotic species, with scientists from the University of Washington and the San Francisco Estuary Institute. The cooperative project brought together 19 experts from a variety of institutions and disciplines to sample 25 sites in Puget Sound between Blaine and Shelton. The sampled sites represented a range of environmental and anthropogenic conditions. The expedition adopted methods used by previous San Francisco expeditions (Cohen and Carlton, 1995) that focused primarily on sampling floating docks and associated benthic habitats. These areas were chosen because they could be easily accessed and provided an obvious pathway for introduction and a protected location for larval settlement and survival.

The Puget Sound Expedition collected and identified 39 non-indigenous invertebrates, algae and vascular plant species in six days of sampling. Much analysis remains to be completed, including genetic analysis of mussels and identification of plankton samples. Some highlights of the study's findings to date include the following:

- Ten non-indigenous species were found that had not been previously reported in Puget Sound. These discoveries increased the number of known non-indigenous species in Puget Sound salt and brackish waters to 52.
- Puget Sound appears to have far fewer exotics than San Francisco Bay, which is known to have over 150 species in habitats similar to those of Puget Sound. This comparison should not put us at ease, however, because even a single exotic species has the potential to greatly change the Puget Sound ecosystem.
- Approximately one-half of Puget Sound's non-indigenous species whose native range is known are from the North Atlantic and the other half are from the Western Pacific. The importance of the two source regions appears to have shifted over time. The majority of species discovered before 1950 are from the North Atlantic, while the majority of species discovered after 1950 are from the Western Pacific (Table 20, 102).
- Initial analysis of the distribution of non-indigenous species collected by the expedition reveals no obvious trends in the distribution of exotic species throughout the Sound with regard to salinity, temperature or region. The highest number of introductions was found at Shelton, Des Moines, Seabeck and Blaine, which represent the northern and southern sampling endpoints and two midpoints in the study area.

Non-Native Copepods in Elliott Bay. In the summer of 1998 several examples of an introduced Asian copepod, *Pseudodiaptomus marinus,* were observed in samples of epibenthos (animals living attached to the sea bottom or moving freely over it) collected from Seattle's Elliott Bay. This was the first observation of this genus of copepod in Puget Sound.

In the spring of 1999, researchers at the University of Washington repeated sampling for *P. marinus* in order to determine its status in Elliott Bay. They did not find *P. marinus* or any of the other new Asian copepods found the previous spring. It appears

Exotic copepods in coastal estuaries

Scientists at the University of Washington are currently conducting research on another non-native Asian copepod, *Pseudodiaptomus inopinus,* a crustacean likely introduced into Pacific Northwest coastal estuaries via ballast water. One phase of the study includes a survey of estuaries between southern British Columbia and northern California to be conducted during the summer of 2000. The purpose of the survey is to determine whether or not *P. inopinus* has invaded new estuaries and increased its geographic range and to verify that it has persisted in estuaries in which it has been recorded before. *P. inopinus* has not been recorded in Puget Sound.

Table 20. Origins, first records and mechanisms of introduction of non-indigenous species collected by the Puget Sound Expedition.

General Taxon	Species	Native Range	First Pacific Coast Record	First Puget Sound Record	Possible Mechanism of Introduction
Seaweeds	*Sargassum muticum*	Japan	1944	?	OJ
Anthophyta	*Spartina anglica*	England	1961-62	1961-62	MR
	Zostera japonica	W Pacific	1957	?	OJ
Foraminifera	*Trochammina hadai*	Japan	1983	1997	BW,SF,OJ
Cnidaria	*Cordylophora caspia*	Black/Caspian Seas	ca. 1920	ca. 1920	BW,SF
	Diadumene lineata	Asia	1906	<1939	OA,SF
Annelida	*Hobsonia florida*	NW Atlantic	1940	1940	?
	Pseudopolydora sp.	?	?	?	?
Mollusca	*Batillaria attramentaria*	Japan	1924	1924	OJ
	Crepidula fornicata	NW Atlantic	1905	1905	OA
	Myosotella myosotis	Europe?	1871	1927	OA(SB,SF)
	Crassostrea gigas	Japan	1875	1875	OJ
	Mya arenaria	NW Atlantic	1874	1888-89	OA
	Nuttallia obscurata	Japan, Korea (China?)	1989	1991-96	BW
	Venerupis philippinarum	NW Pacific	1924	1924	OJ
Copepoda	*Choniostomatid copepod*	?	?	1998	?
Cumacea	*Nippoleucon hinumensis*	Japan	1979	1998	BW
Isopoda	*Limnoria tripunctata*	not known	1871 or 1875	?	SF
Amphipoda	*Ampithoe valida*	NW Atlantic	1941	?	BW,OA,SF
	Caprella mutica	Japan to Vladivostok	1973-77	1998	BW,OJ
	Corophium acherusicum	not known	1905	1974-75	OA,SF
	Corophium insidiosum	N Atlantic	1915	1930	OA,SF
	Eochelidium sp.	Japan or Korea	early 1990s?	1997	BW
	Grandidierella japonica	Japan	1966	?	BW,OJ,SF
	Jassa marmorata	NW Atlantic	1941	?	BW, SF
	Melita nitida	NW Atlantic	1938	1966	BW,OA,SB,SF
	Parapleustes derzhavini	W Pacific?	1904	1998	SF
Entoprocta	*Barentsia benedeni*	Europe	1929	<1998	OJ,SF
Bryozoa	*Bowerbankia gracilis*	NW Atlantic?	<1923	<1953	OA,SF
	Bugula sp. 1	?	?	1993	?
	Bugula sp. 2	?	?	1998	?
	Bugula stolonifera	NW Atlantic	<1978	1998	SF
	Cryptosula pallasiana	N Atlantic	1943-44	1998	OA,SF
	Schizoporella unicornis	NW Pacific	1927	1927	OJ,SF
Urochordata	*Botrylloides violaceus*	Japan	1973	1977	OJ,SF
	Botryllus schlosseri	NE Atlantic	1944-47	?	OA,SF
	Ciona savignyi	Japan?	1985	1998	BW,SF
	Molgula manhattensis	NW Atlantic	1949	1998	BW,OA,SF
	Styela clava	China to Okhotsk Sea	1932-33	1998	BW,OJ,SF

This list of species is provisional pending further taxonomic work and review by expedition members and associates.
Native ranges, dates of first record (planting, collection, observation or report) in Puget Sound and on the Pacific Coast of North America, and possible initial mechanisms of introduction to the Pacific Coast are given. First records consisting of written accounts that do not state the date of planting, collection or observation are preceded by the symbol "<". Mechanisms given in parentheses indicate less likely mechanisms. Mechanisms are listed as:

OA-with shipments of Atlantic oysters
SF-in ship fouling or boring
BW-in ship ballast water or seawater system
OJ-with shipments of Japanese oysters
SB-in solid ballast
MR-planted for marsh restoration or erosion control

that the non-native species observed in 1998, which had probably been introduced from ballast water releases, may not have successfully reproduced in Elliott Bay.

As far as is known by scientists, the only copepod introductions that are established in Elliott Bay are two species of Stephos, *S. pacificus* and another unidentified and possibly undescribed species. These species co-occur in shallow subtidal sediments around the bay and can be quite abundant (J. Cordell, personal communication).

European Green Crab. The European green crab *(Carcinus maenus)*, a non-native species, made its appearance on the outer coast of Washington in June 1998. The European green crab is a federally recognized nuisance species and has been declared an aquatic nuisance species by the Washington Department of Fish and Wildlife.

The European green crab is an introduced species of particular concern for many reasons. It is a relatively small crab, but a voracious predator for its size. It preys upon a wide variety of plants and animals, but prefers small bivalves, including commercially and recreationally important clams, oysters and mussels. An adult green crab can consume large quantities of these organisms. The crab has also been known to prey upon Dungeness crab (*Cancer magister*) of equal or lesser size. The European green crab is an accomplished burrower, and the possible effects of its digging activities on the benthic environment and integrity of shore banks is unknown. The crab is found along the shoreline in water up to, and sometimes exceeding, 30 feet deep, in the high intertidal zone and in salt marshes.

In preparation for the potential spread of the green crab into Puget Sound, a monitoring program was launched to increase the probability of detecting green crabs in Puget Sound, the Strait of Juan de Fuca and the San Juan Islands. Fish and Wildlife and other government agency staff, volunteer groups, tribes, shellfish growers, schools and individual citizens have been monitoring for the presence of C. maenus, primarily by setting baited traps in the intertidal zone. In addition, the Department of Fish and Wildlife and the U.S. Fish and Wildlife Service have contracted with Adopt a Beach, a non-profit volunteer group, to train and coordinate volunteers to monitor for the European green crab in Puget Sound. With its large volunteer base and membership from throughout the Puget Sound region, Adopt a Beach has been able to provide broad geographical monitoring coverage in a very short period of time. Between July and September 1999, Adopt a Beach trained approximately 35 volunteers, establishing 32 monitoring sites ranging from south Puget Sound to the San Juan Islands to the U.S./Canadian border. Through the cooperation and combined efforts of all participating groups and individuals, approximately 80 European green crab monitoring sites were established in 1999 (Figure 67, page 104). As of February 2000, no European green crabs have been found in Puget Sound.

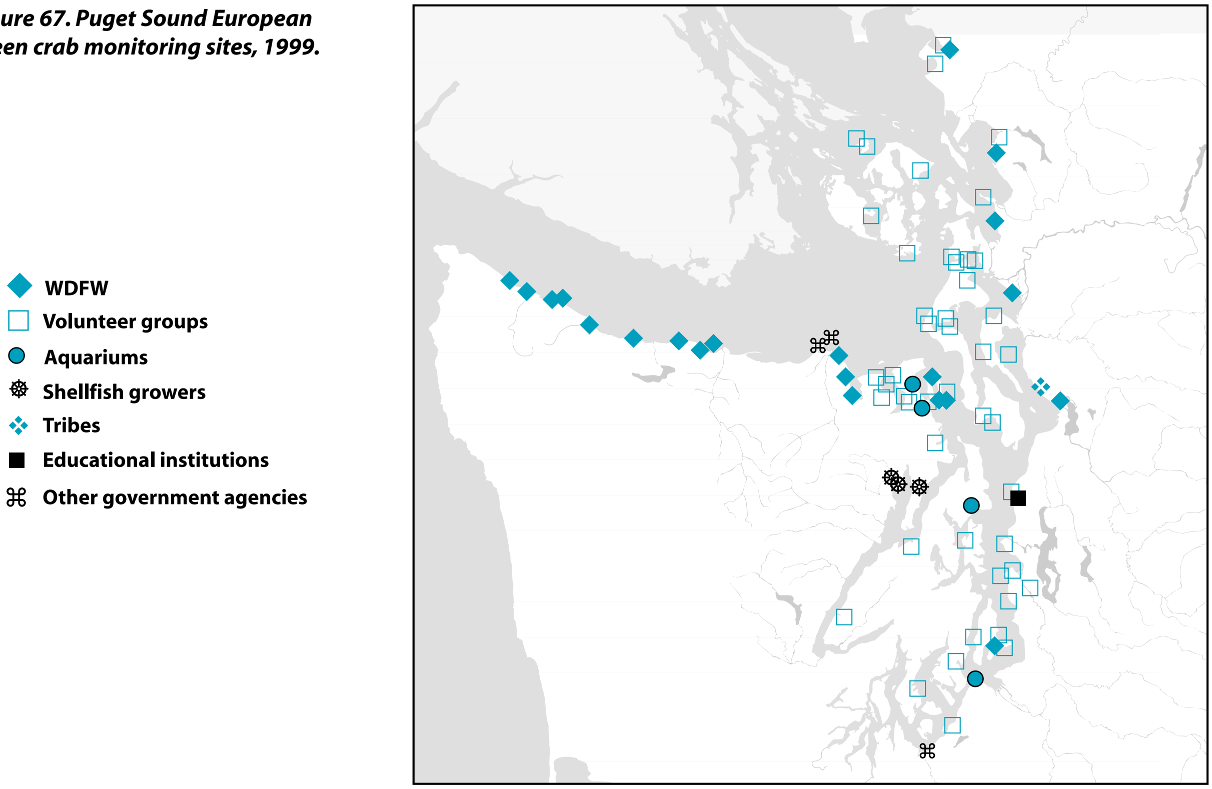
In June 1999, an adult female green crab was discovered in Useless Inlet, an area of commercial oyster leases on the west coast of Vancouver Island. During the course of the summer, four more adults were found in the same location. In August 1999, four additional adult green crabs were found in the Strait of Juan de Fuca in the vicinity of Victoria. It is believed that because the crabs found in British Columbia were adult size, they must have arrived in 1997 or 1998—likely as a result of coastal current transport of larvae. The Department of Fisheries and Oceans Canada is currently planning to begin green crab monitoring in British Columbia.

***Spartina* (Cordgrass).** *Spartina,* commonly known as cordgrass, is a noxious weed that severely disrupts native saltwater ecosystems, alters fish, shellfish and bird habitat, and increases the threat of floods. Three species of *Spartina* have been introduced to and have become established in nearshore environments in western Washington.

The European green crab in Washington's coastal estuaries

The Department of Fish and Wildlife, with assistance from shellfish growers, the Shoalwater Tribe and students from The Evergreen State College, have been monitoring the green crab in Willapa Bay and Grays Harbor (estuaries outside of Puget Sound) since 1998. Based on data about the "catch per unit effort" of fishing for green crabs, Fish and Wildlife scientists estimate that the number of green crabs in Willapa Bay actually decreased from 1998 to 1999. Although it is too soon in the monitoring effort to draw conclusions, there are many possible explanations for the observed decrease: the summer 1998 fishing effort by Fish and Wildlife scientists and shellfish growers may have reduced the population; the crabs may have spread throughout the bay away from the trapping areas around the mouth of the bay where they were concentrated in 1998; as they grew larger, the crabs may have been subject to predation by native species. Only after continued long-term monitoring and directed research studies will the reasons for the changes in numbers of green crabs trapped become more clear.

Figure 67. Puget Sound European green crab monitoring sites, 1999.



Source: Department of Fish and Wildlife.

In Puget Sound, known Spartina infestations occur at a few locations along the Strait of Juan de Fuca and into Hood Canal, at three locations in San Juan County (one each at San Juan, Orcas and Lopez islands), in numerous areas along the shorelines of Skagit, Island and Snohomish counties, and at a few locations along the shorelines of King and Kitsap counties (see Figure 68). Spartina has not been found south of the Tacoma Narrows in Puget Sound.

The Washington Department of Agriculture (Agriculture) coordinates a *Spartina* Eradication and Control Program. As part of this program, Agriculture conducts all control work in San Juan, Clallam, Jefferson, Kitsap and King counties and also coordinates the entire Puget Sound/Hood Canal effort. The agency allocates funding and other support to Island, Snohomish and Skagit counties, Adopt a Beach, private landowners and the Swinomish and Suquamish tribal communities. In addition, Department of Fish and Wildlife staff conduct substantial control work on their property throughout northern Puget Sound and assist county control efforts as time and funding permit.

As of the beginning of the 1999 control season, the control efforts of Agriculture and its partners have resulted in significant progress in reducing the size of Puget Sound *Spartina* infestations (and in some cases, eliminating them). As Agriculture and collaborators such as Fish and Wildlife succeed at reducing or eliminating smaller, outlying populations of *Spartina* that have the potential to greatly increase in area, larger areas of infestation, such as South Skagit Bay, will become a bigger priority and the focus of additional funding.

Previous introductions of the European green crab to Washington

Between Pacific Tides (Ricketts and Calvin, 1968) notes the appearance of the European green crab in Willapa Bay in 1961. It is the consensus that Ricketts and Calvin would not have included this report in their book unless it was substantiated. However, no other details about the sighting are available. Documentation in the form of a specimen, photograph or detailed written description has apparently been lost. In any case, it is unlikely that a population of European green crabs became established in Willapa Bay after that initial sighting.

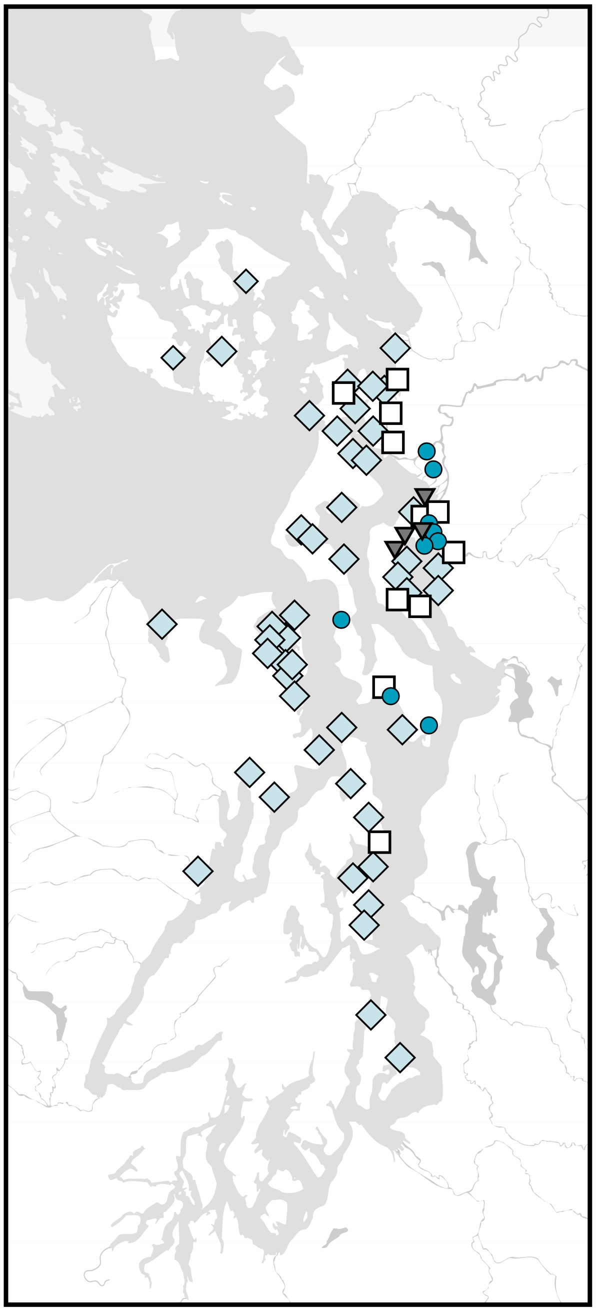


Figure 68. Approximate 1999 locations and sizes of known Spartina infestations in Puget Sound and Hood Canal.

- < 1 acre
- 1-5 acres
- 6-100 acres
- >100 acres

Acreage values are for estimated acres totally covered by *Spartina*.

Data from Washington State Department of Agriculture.

Acting on the Findings

Information presented in this chapter suggests a number of follow up actions to improve the understanding and management of Puget Sound's biological resources. One suggestion sprinkled throughout the preceding pages is that agencies should continue and expand efforts to monitor the abundance, as well as the condition, of Puget Sound organisms and habitats. Information from abundance monitoring should be used to manage species harvests, where applicable, and to shape and direct other resource management actions. Recommended actions related to specific biological resources include the following:

- Nearshore vegetation monitoring should be expanded to include evaluation of trends in the extent of eelgrass beds in Puget Sound.

The Department of Natural Resources is currently developing a program to monitor temporal trends in intertidal and subtidal eelgrass beds. Information from this effort will increase knowledge about trends over time in the distribution and abundance of eelgrass beds along Puget Sound's shoreline.

- State agencies such as the Department of Ecology, local governments, etc. should use Natural Resources' data on kelp resources in the Strait of Juan de Fuca and the agency's nearshore inventory data for Whatcom, Skagit and the northern portion of Island counties to help with nearshore resource management, including oil spill response planning and land-use planning.
- Scientists should continue to develop improved approaches to characterizing phytoplankton biomass in Puget Sound, possibly including the use of remote sensing and/or sensors deployed on moorings.
- The Department of Fish and Wildlife should expand fishery-independent monitoring of marine fish abundance to provide consistent data on stock status.
- Scientists from the region should study ecosystem relationships in south Puget Sound to develop information about the causes of the declines in marine survival in salmon from south Puget Sound, as well as possible remedies to this problem.
- Resource managers should evaluate ways to restore and recover fish populations in Puget Sound (such as those found on pages 84 to 90).
- U.S. and Canadian scientists should collaborate to expand winter aerial surveys of bird abundance and distribution into the inland coastal waters of British Columbia in order to better define habitat use and population size for more of the Puget Sound/Georgia Basin ecosystem.
- Scientists should evaluate harbor seal diets in other areas of Puget Sound to provide information about the predation pressures that seals exert on various fish species.
- Scientists in the region should conduct additional surveys of exotic species in habitats not assessed during the Puget Sound Expedition to develop a more comprehensive list of exotic species in Puget Sound.
- Resource management agencies should support basic research to improve our understanding of exotic species that may be introduced to Puget Sound as well as those that are already established in the estuary. Agencies should also develop response plans that can be implemented in the event of exotic species introductions to Puget Sound.